US009070330B2

(12) United States Patent
Tamaki

(10) Patent No.: US 9,070,330 B2
(45) Date of Patent: Jun. 30, 2015

(54) **DISPLAY APPARATUS WITH TRANSMISSIVE AND REFLECTIVE SUBPIXELS**

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(73) Assignee: **JAPAN DISPLAY INC.**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 195 days.

(21) Appl. No.: **13/449,542**

(22) Filed: **Apr. 18, 2012**

(65) **Prior Publication Data**

US 2012/0274679 A1 Nov. 1, 2012

(30) **Foreign Application Priority Data**

Apr. 28, 2011 (JP) 2011-100516

(51) **Int. Cl.**
G09G 3/36 (2006.01)

(52) **U.S. Cl.**
CPC ***G09G 3/3607*** (2013.01); *G09G 3/3648* (2013.01); *G09G 2300/0452* (2013.01); *G09G 2300/0456* (2013.01)

(58) **Field of Classification Search**
CPC G09G 3/3607
USPC 345/87–88, 92
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,100,861	A *	8/2000	Cohen et al.	345/88
7,808,466	B2 *	10/2010	Morimoto et al.	345/87
8,502,839	B2 *	8/2013	Tseng et al.	345/690
2005/0140622	A1 *	6/2005	Lee et al.	345/88
2006/0284811	A1 *	12/2006	Huang	345/92
2007/0146242	A1	6/2007	Miller et al.	
2007/0205972	A1 *	9/2007	Asao et al.	345/88
2008/0084376	A1 *	4/2008	Hirota et al.	345/88
2008/0136982	A1 *	6/2008	Watanabe et al.	349/37
2008/0218461	A1 *	9/2008	Sugita et al.	345/88
2009/0059341	A1	3/2009	Kinugawa et al.	

FOREIGN PATENT DOCUMENTS

JP	2955227	7/1999
JP	2004-198792	7/2004
JP	2005-316203	10/2005
JP	2009-075547	4/2009
WO	2009-025053 A1	2/2009

OTHER PUBLICATIONS

Japanese Office Action dated May 20, 2014, issued in connection with counterpart Japanese Patent Application No. 2011-100516.

Partial European Search Report dated Aug. 7, 2012, in connection with counterpart European Application No. EP 12 16 4739.

* cited by examiner

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(57) **ABSTRACT**

A display apparatus includes a display section including an array of pixels in a two-dimensional matrix, wherein each of the pixels of the display section includes a pair of a subpixel displaying a first primary color, and a subpixel displaying a second primary color being different from the first primary color.

7 Claims, 23 Drawing Sheets

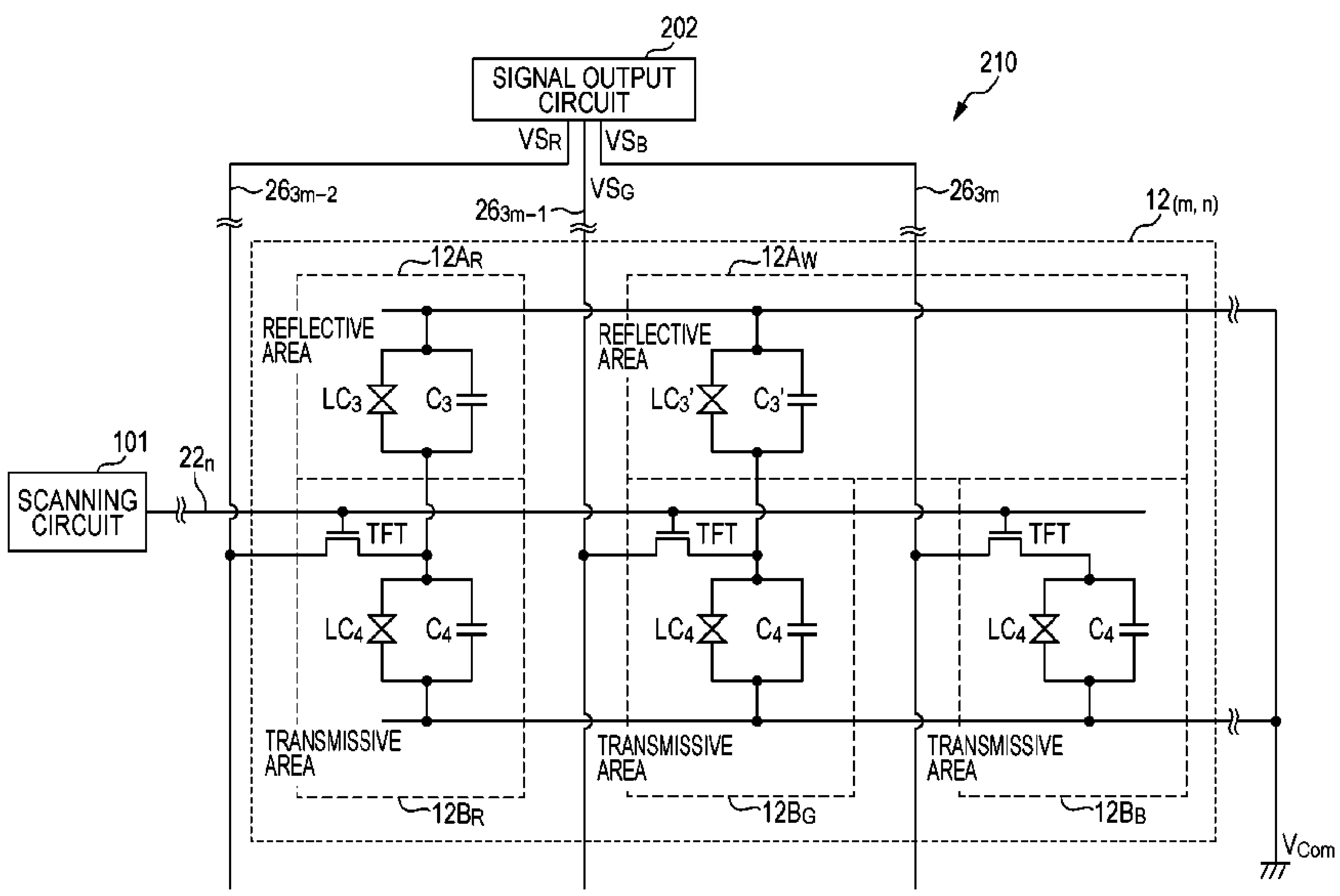


FIG. 1

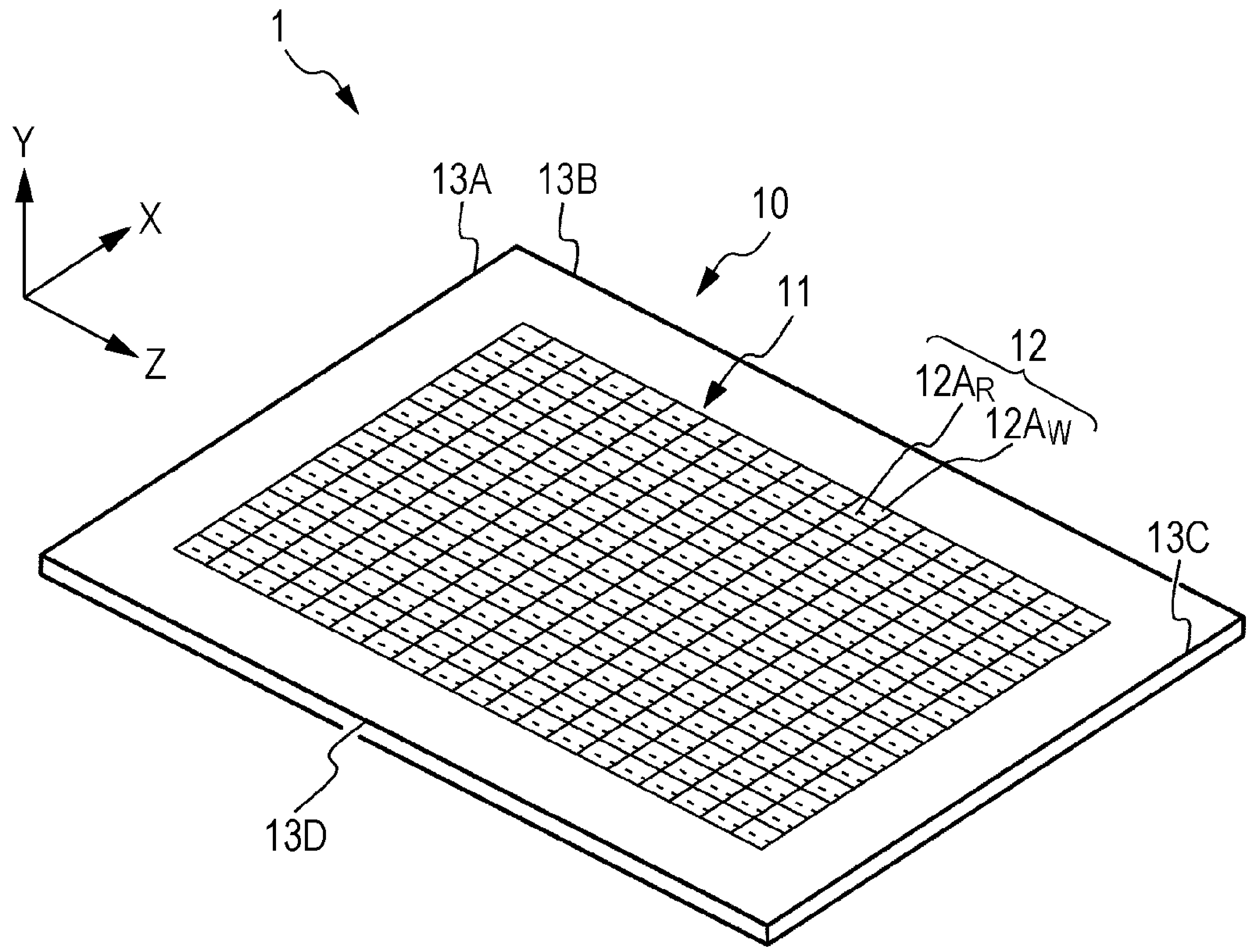


FIG. 2

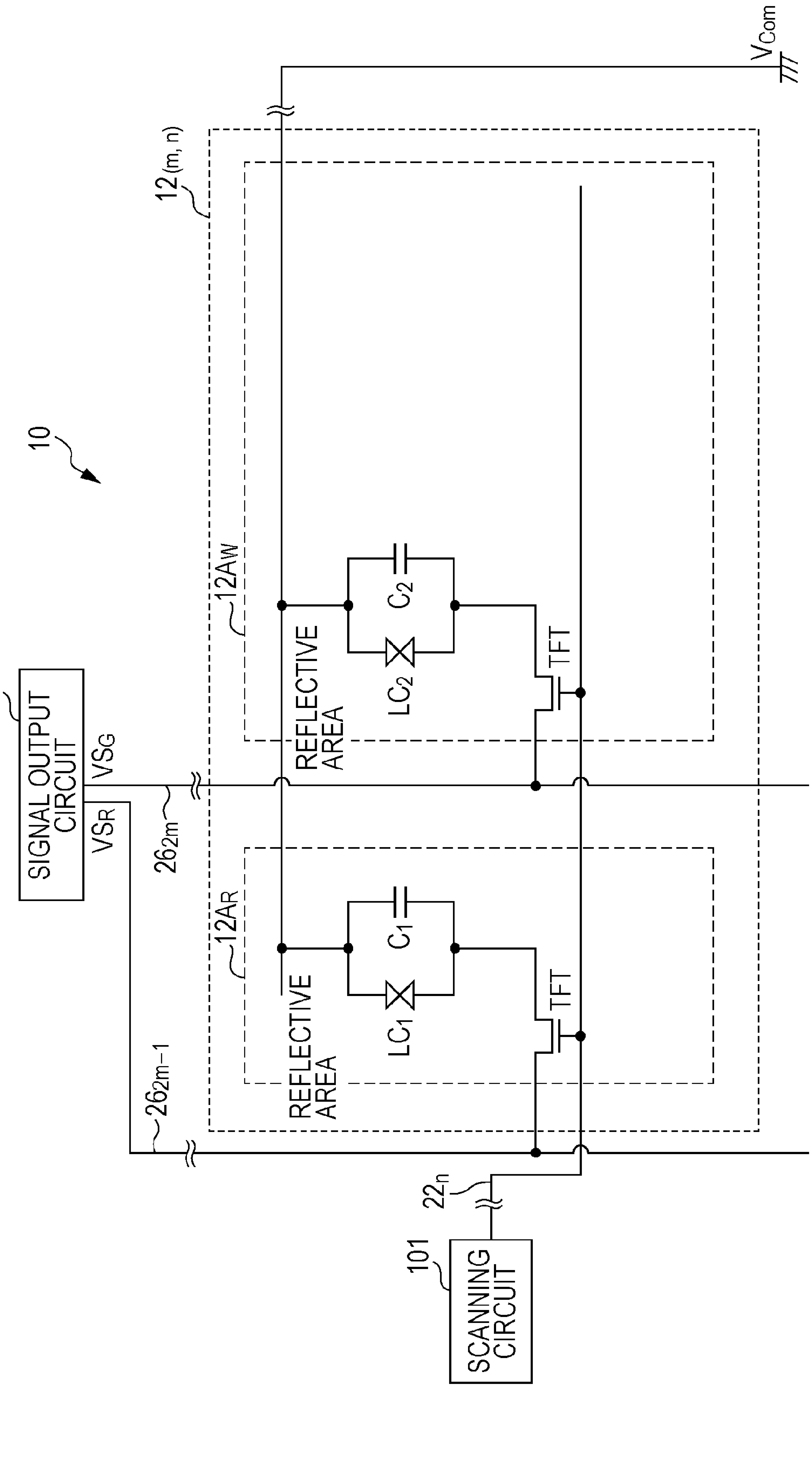

10
102
SIGNAL OUTPUT CIRCUIT
VSG
VSR
262m
262m−1
12(m, n)
12AW
12AR
REFLECTIVE AREA
REFLECTIVE AREA
C2
LC2
C1
LC1
TFT
TFT
VCom
22n
101
SCANNING CIRCUIT

FIG. 3

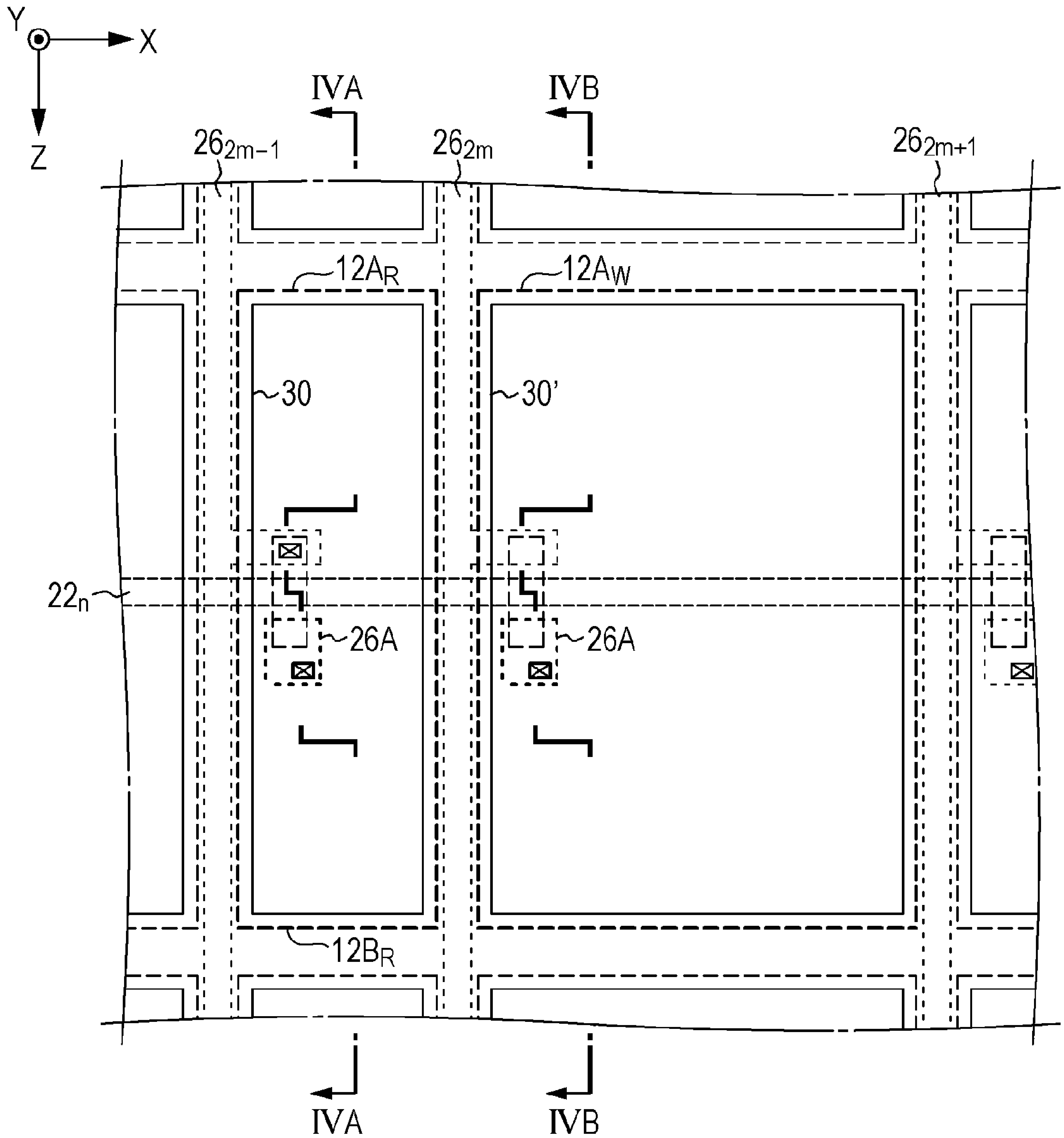
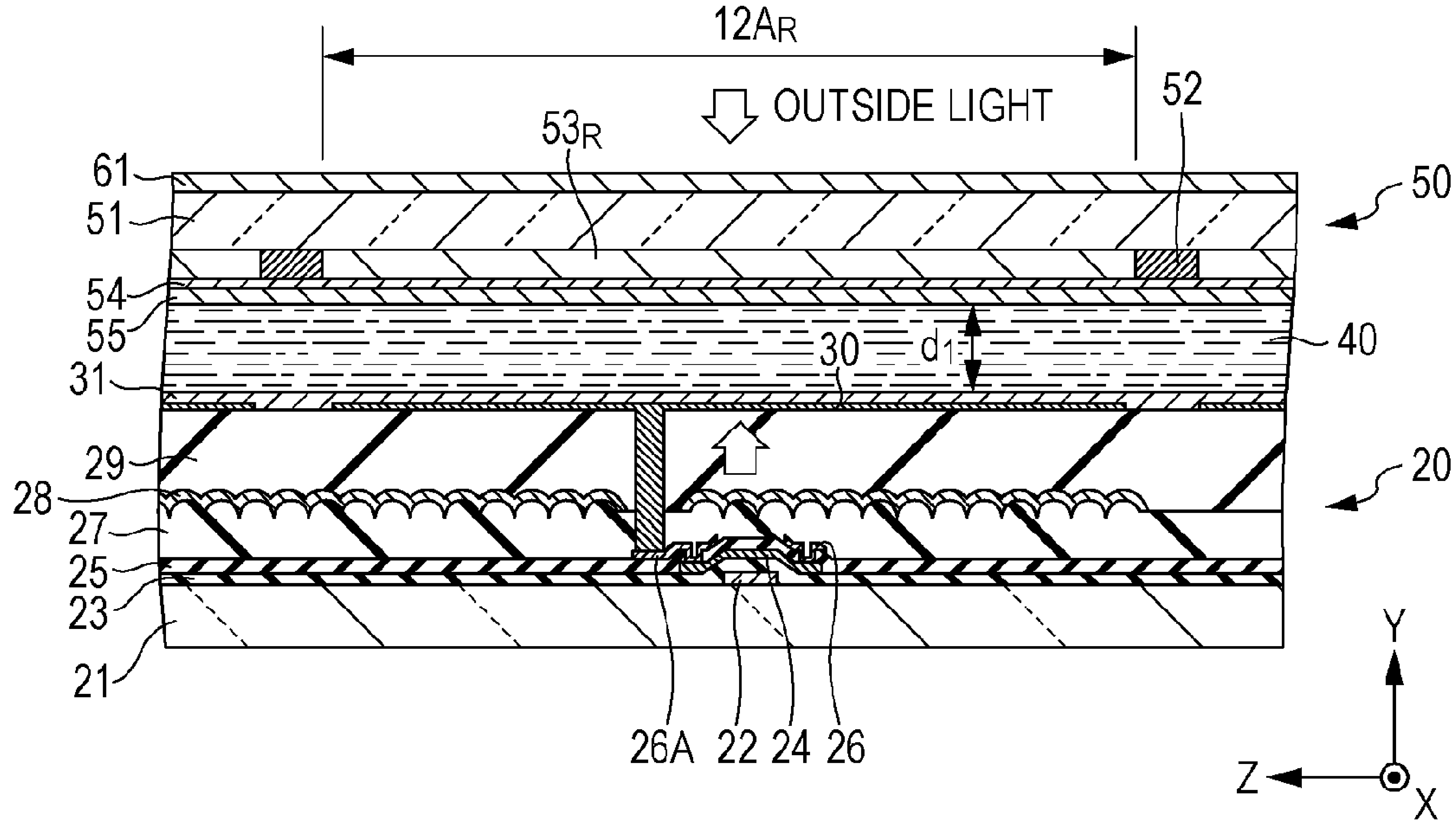
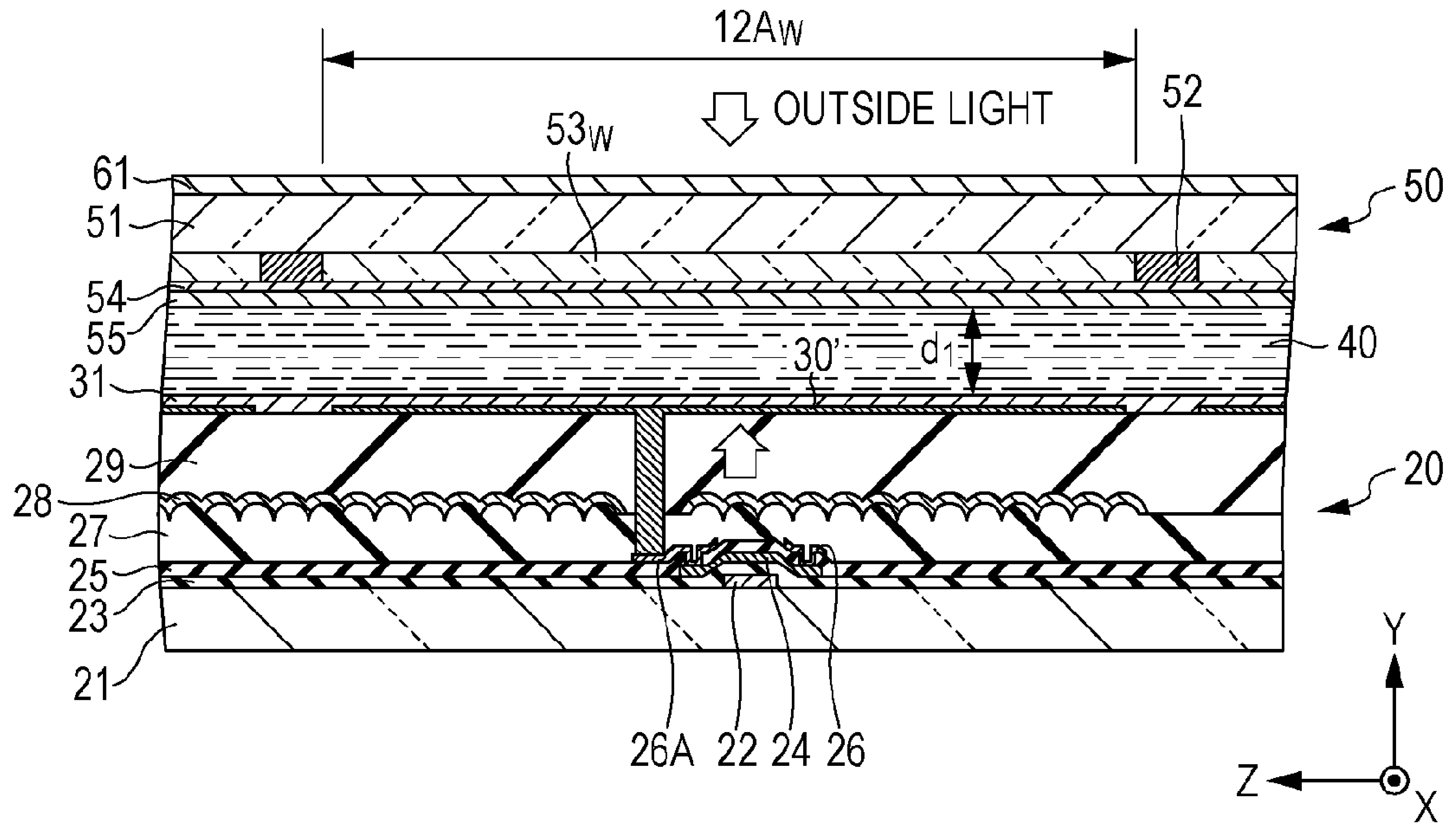

Y
X
Z
IVA
IVB
26_{2m-1}
26_{2m}
26_{2m+1}
$12A_R$
$12A_W$
30
30'
22_n
26A
26A
$12B_R$
IVA
IVB

FIG. 4A



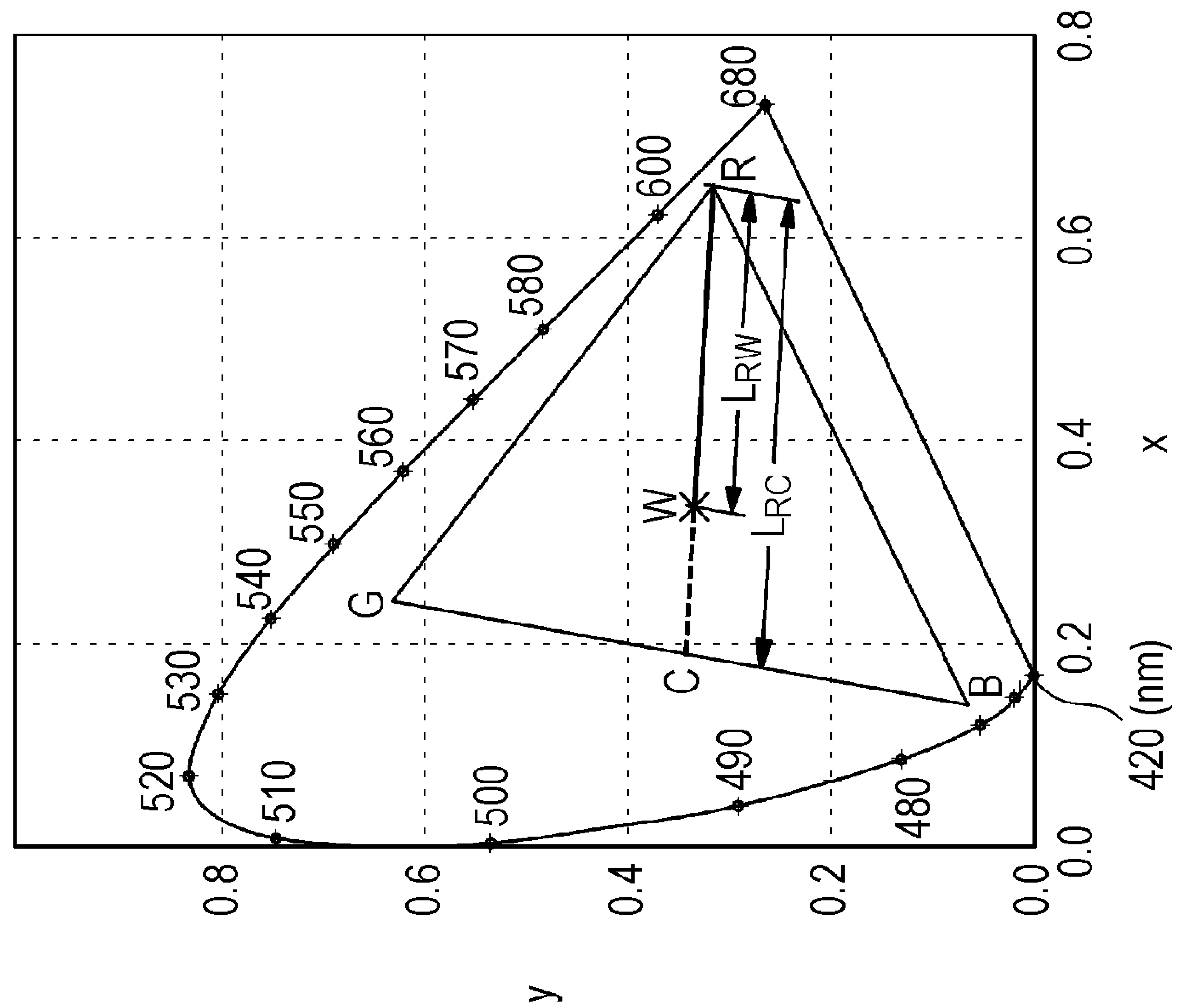
12AR
OUTSIDE LIGHT
53R
52
61
51
50
54
55
30
d1
40
31
29
20
28
27
25
23
21
26A 22 24 26
Y
Z
X

FIG. 4B



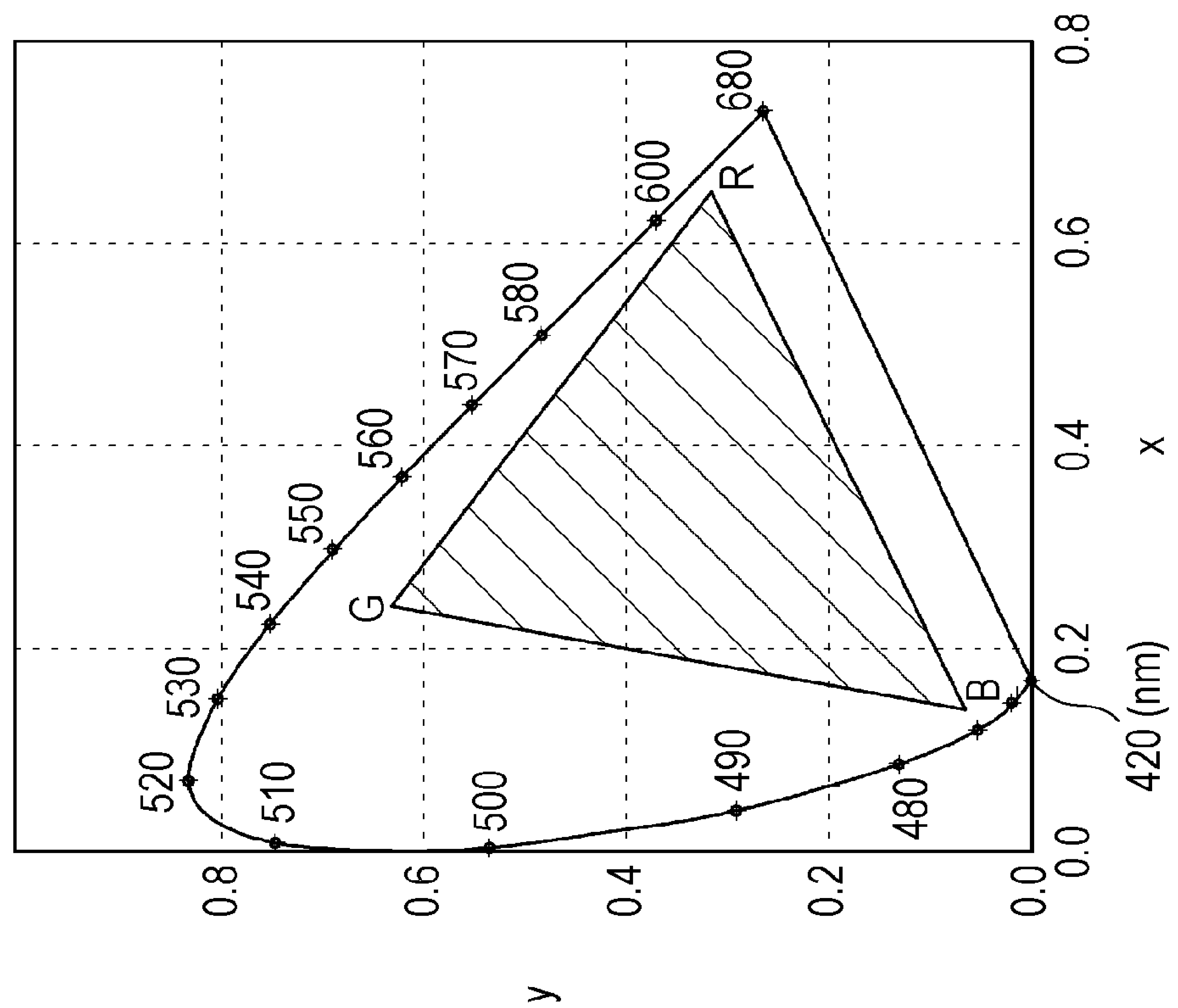
12AW
OUTSIDE LIGHT
53W
52
61
51
50
54
55
30'
d1
40
31
29
20
28
27
25
23
21
26A 22 24 26
Y
Z
X

FIG. 5B



y
x
0.0
0.2
0.4
0.6
0.8
420 (nm)
480
490
500
510
520
530
540
550
560
570
580
600
680
G
R
B
W
C
L_{RW}
L_{RC}

FIG. 5A



y
x
0.0
0.2
0.4
0.6
0.8
420 (nm)
480
490
500
510
520
530
540
550
560
570
580
600
680
G
R
B

FIG. 6

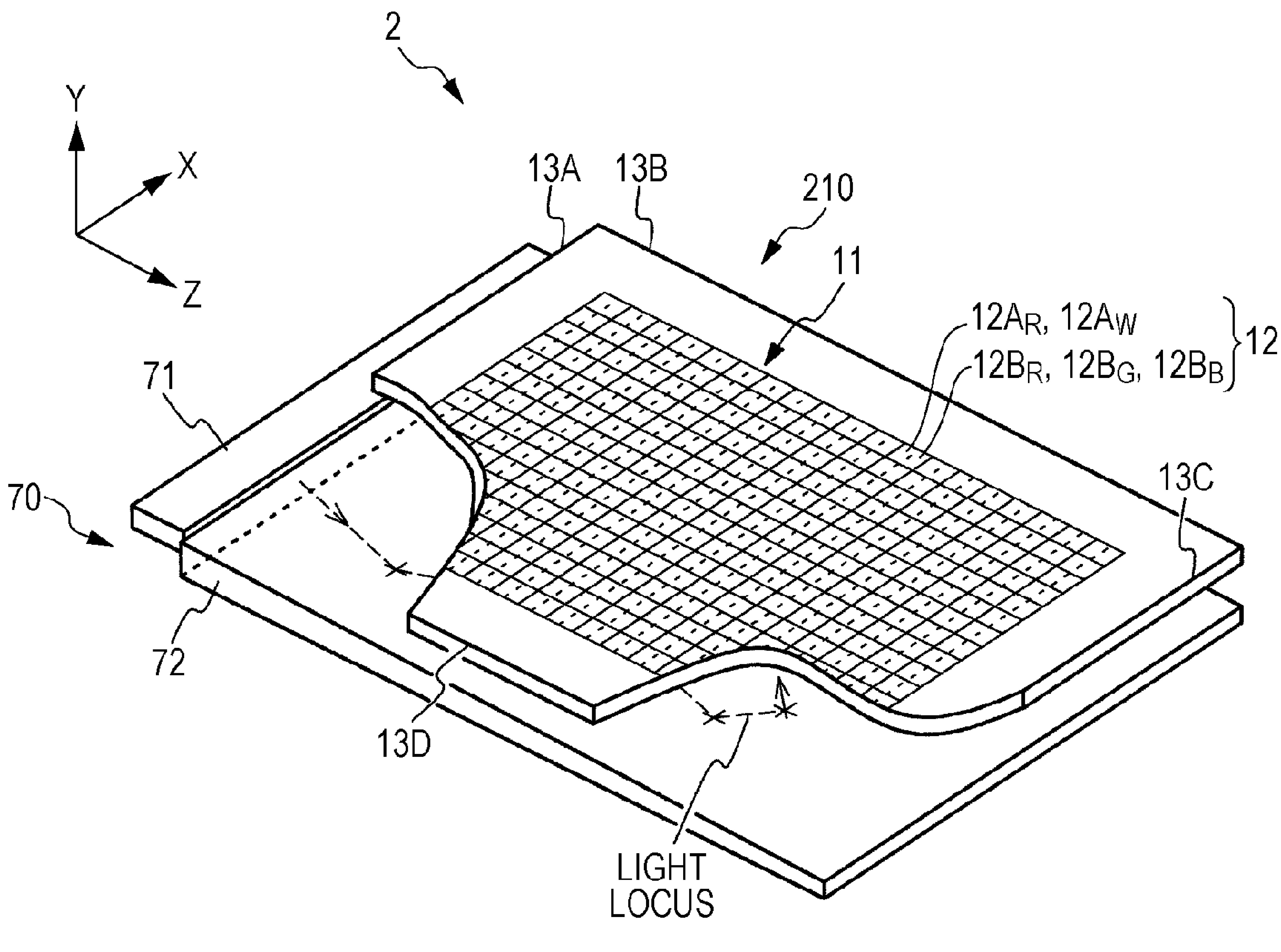

2
Y
X
Z
13A
13B
210
11
$12A_R$, $12A_W$
$12B_R$, $12B_G$, $12B_B$
12
71
70
13C
72
13D
LIGHT
LOCUS

FIG. 7

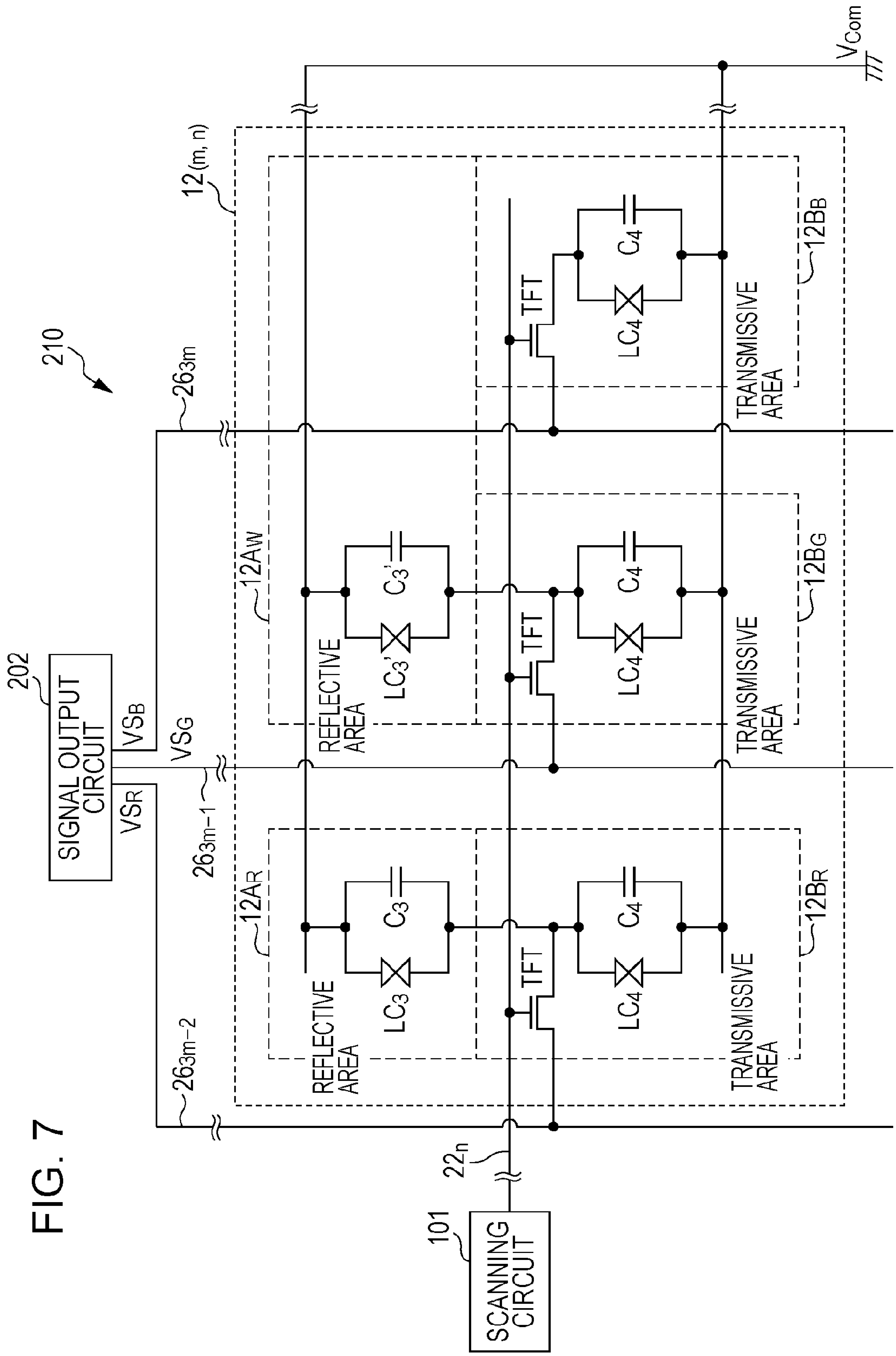

210
202
SIGNAL OUTPUT CIRCUIT
VSB
VSG
VSR
101
SCANNING CIRCUIT
22n
263m
263m−1
263m−2
12(m, n)
12AW
12AR
12BB
12BG
12BR
REFLECTIVE AREA
TRANSMISSIVE AREA
TFT
C3
C3'
C4
LC3
LC3'
LC4
VCom

FIG. 8

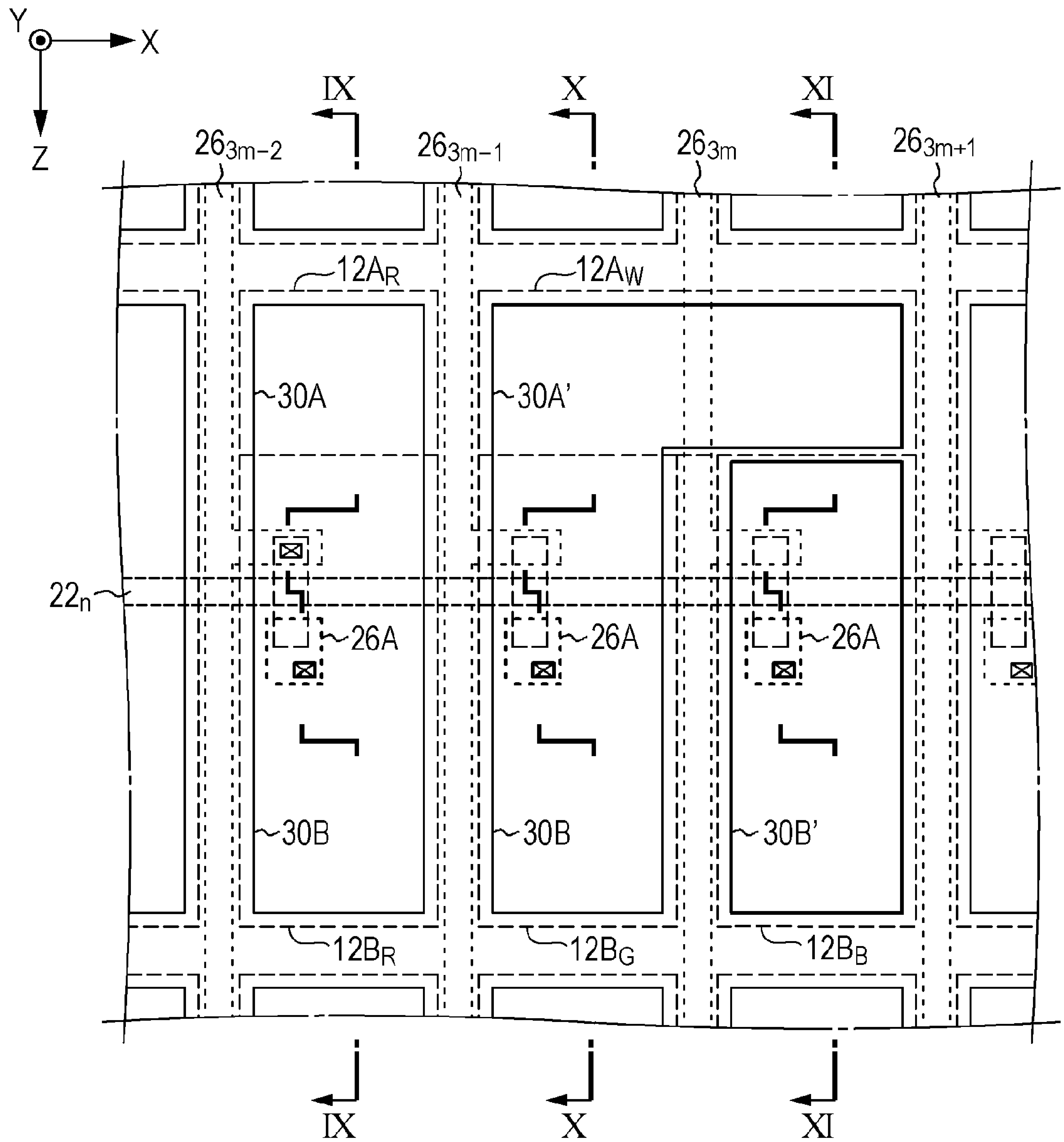
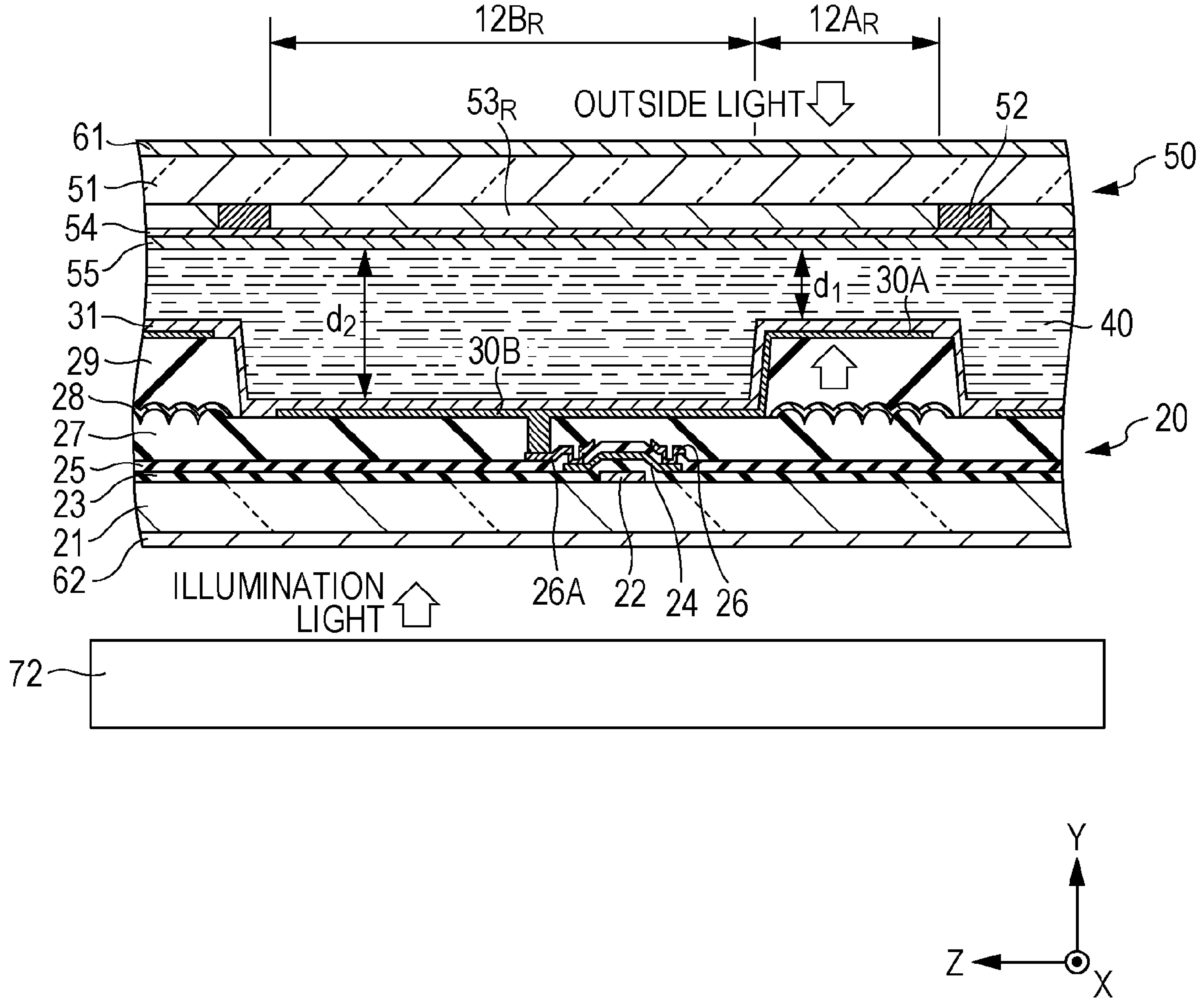

Y
X
Z
IX
X
XI
26_{3m-2}
26_{3m-1}
26_{3m}
26_{3m+1}
$12A_R$
$12A_W$
30A
30A'
22_n
26A
26A
26A
30B
30B
30B'
$12B_R$
$12B_G$
$12B_B$
IX
X
XI

FIG. 9



12B R
12A R
53 R
OUTSIDE LIGHT
52
61
51
50
54
55
d 2
d 1
30A
40
31
29
30B
28
27
20
25
23
21
62
ILLUMINATION LIGHT
26A
22
24
26
72
Y
Z
X

FIG. 10

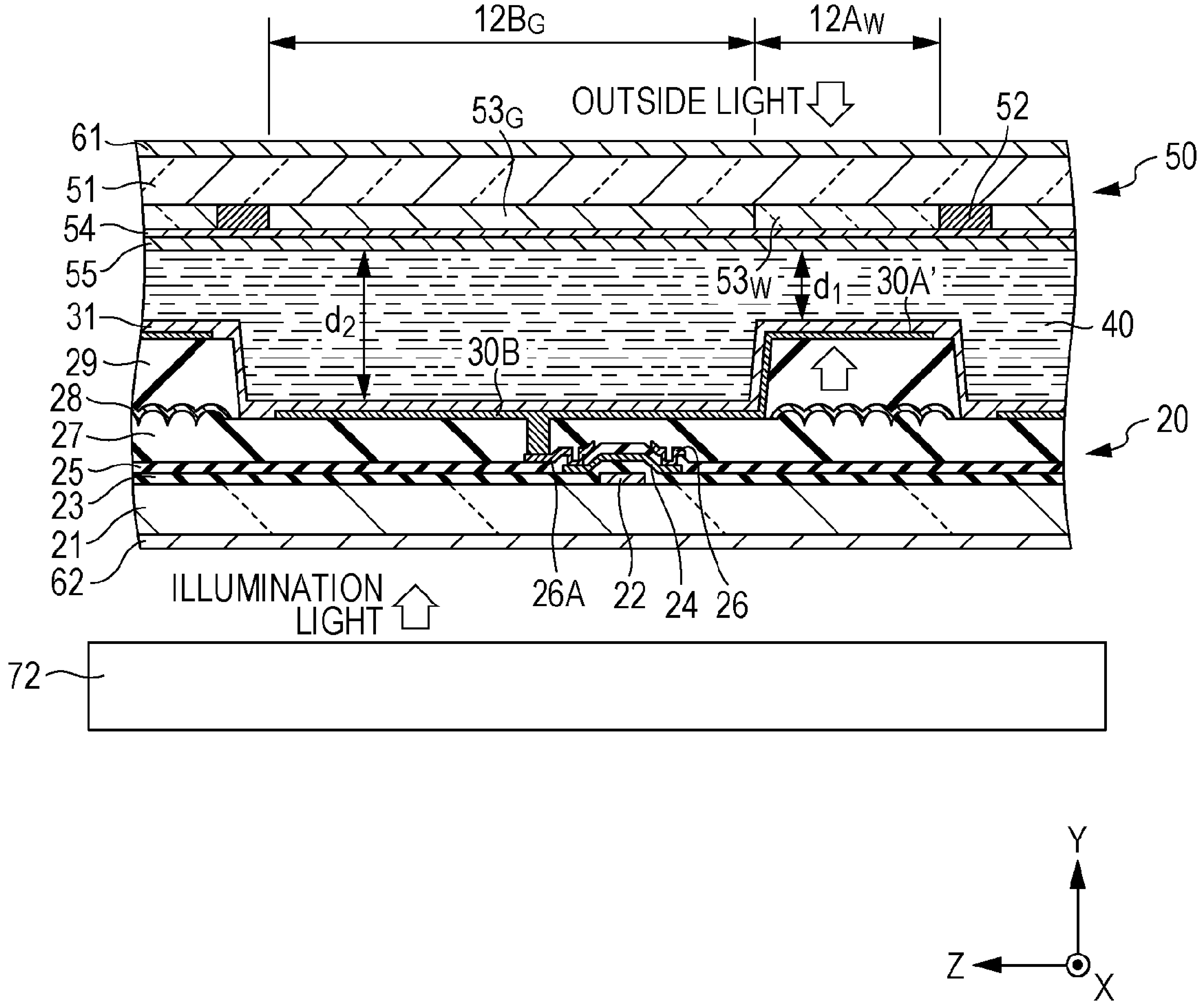
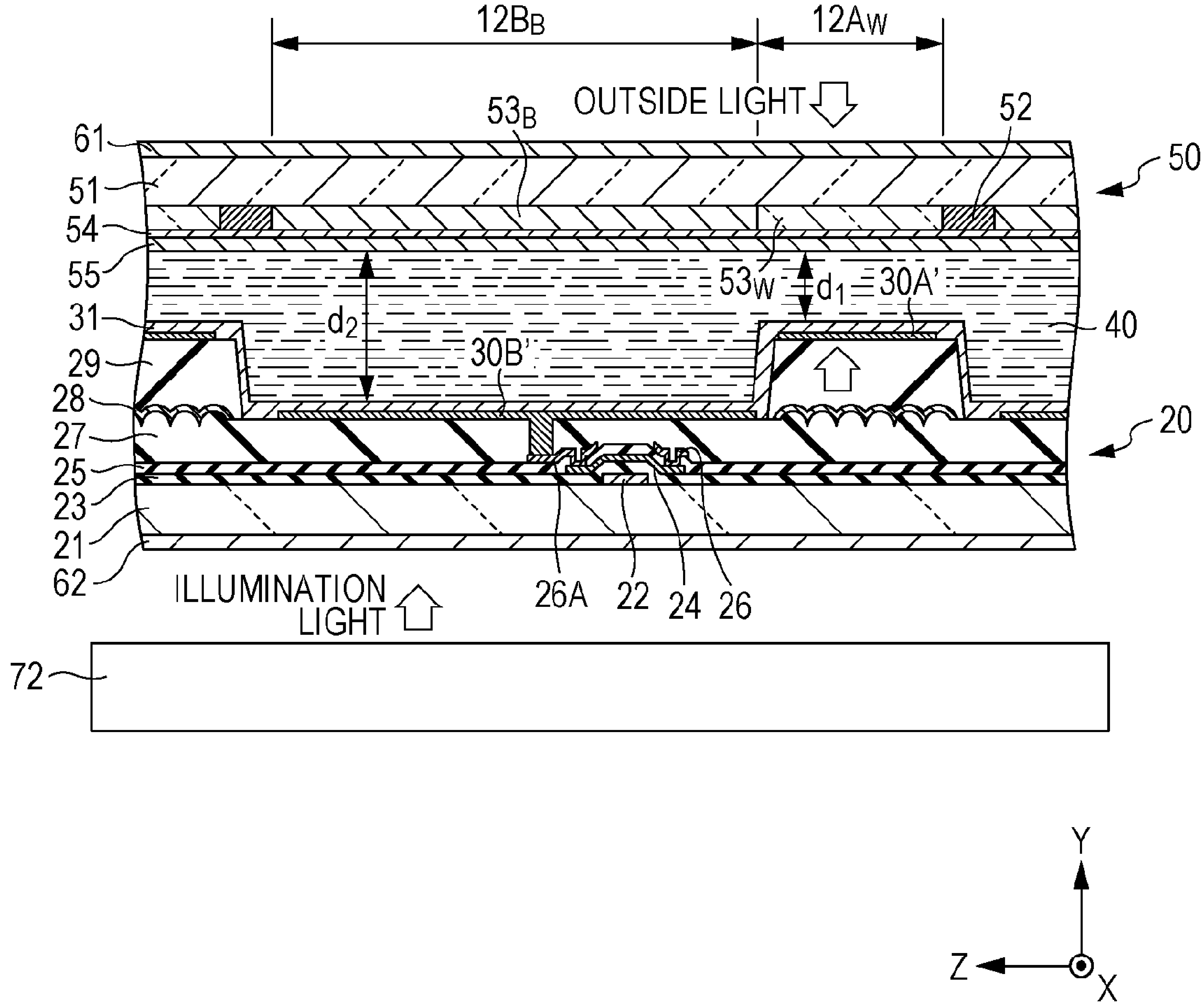

12BG
12AW
OUTSIDE LIGHT
53G
52
61
51
50
54
55
53W
d1
30A'
d2
31
40
29
30B
28
27
20
25
23
21
62
ILLUMINATION LIGHT
26A
22
24
26
72
Y
Z
X

FIG. 11



12B_B
12A_W
OUTSIDE LIGHT
53_B
52
61
51
54
55
31
29
28
27
25
23
21
62
50
d_2
53_W
d_1
30A'
30B'
40
20
ILLUMINATION LIGHT
26A
22
24
26
72
Y
Z
X

FIG. 12

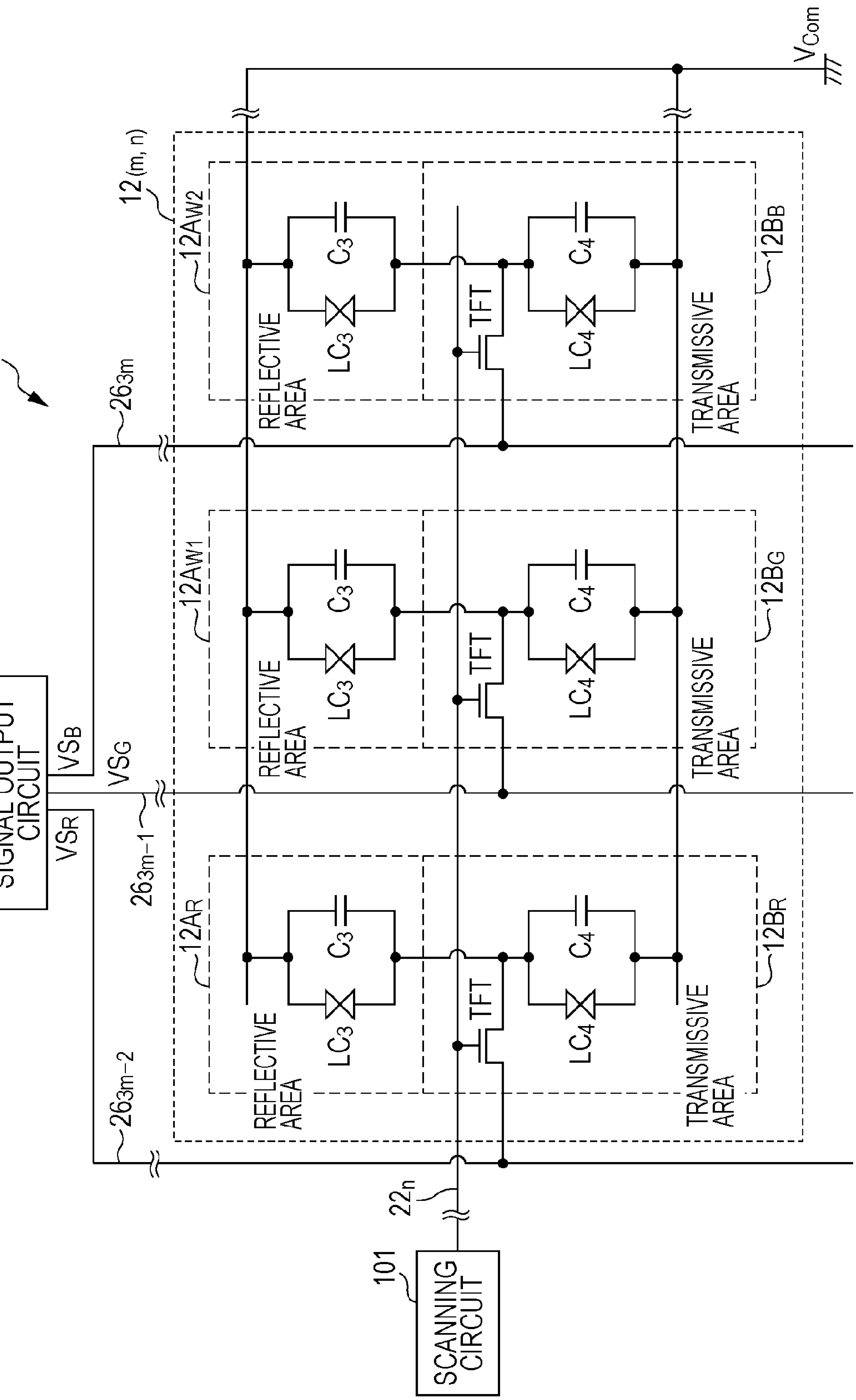
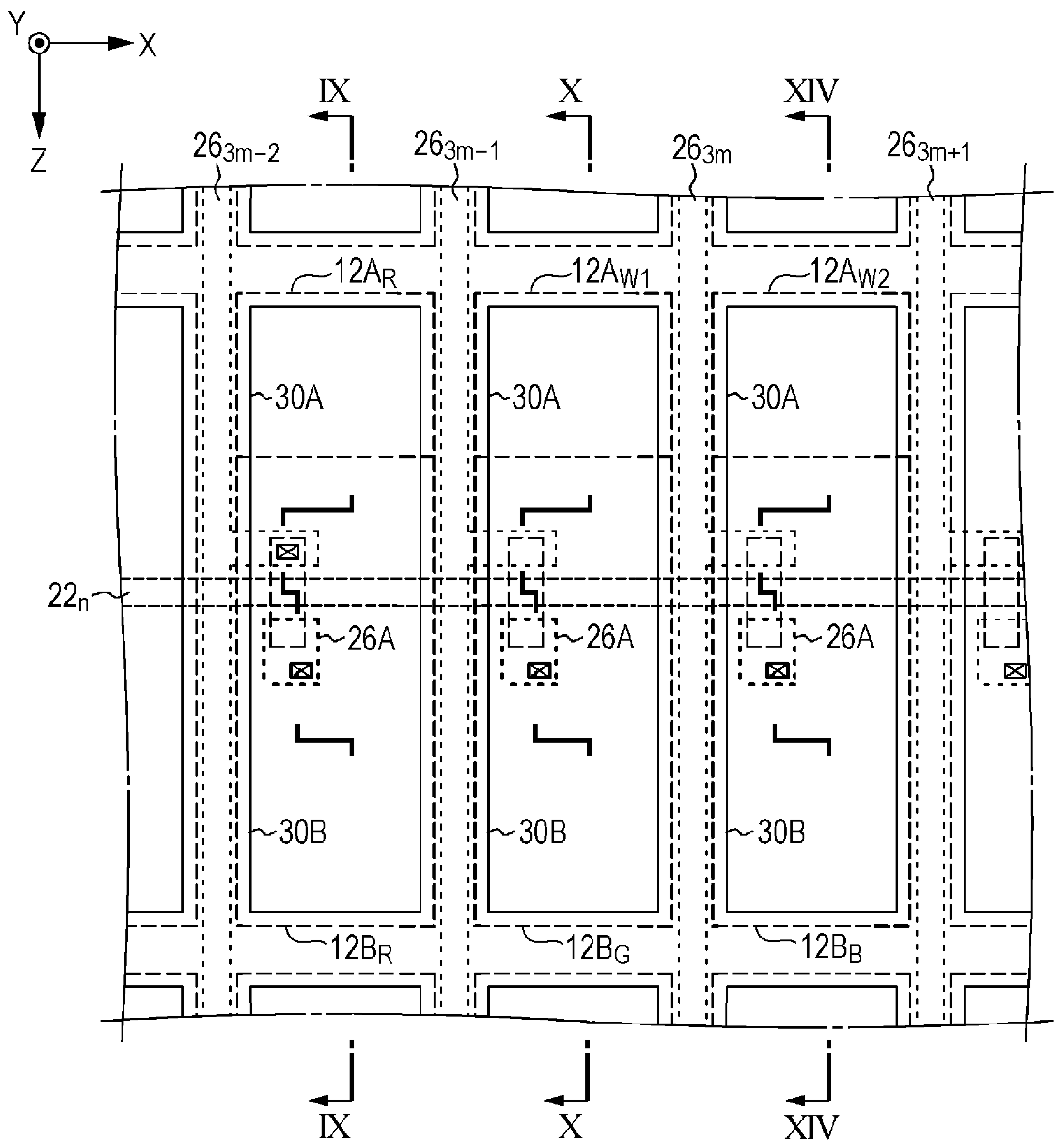
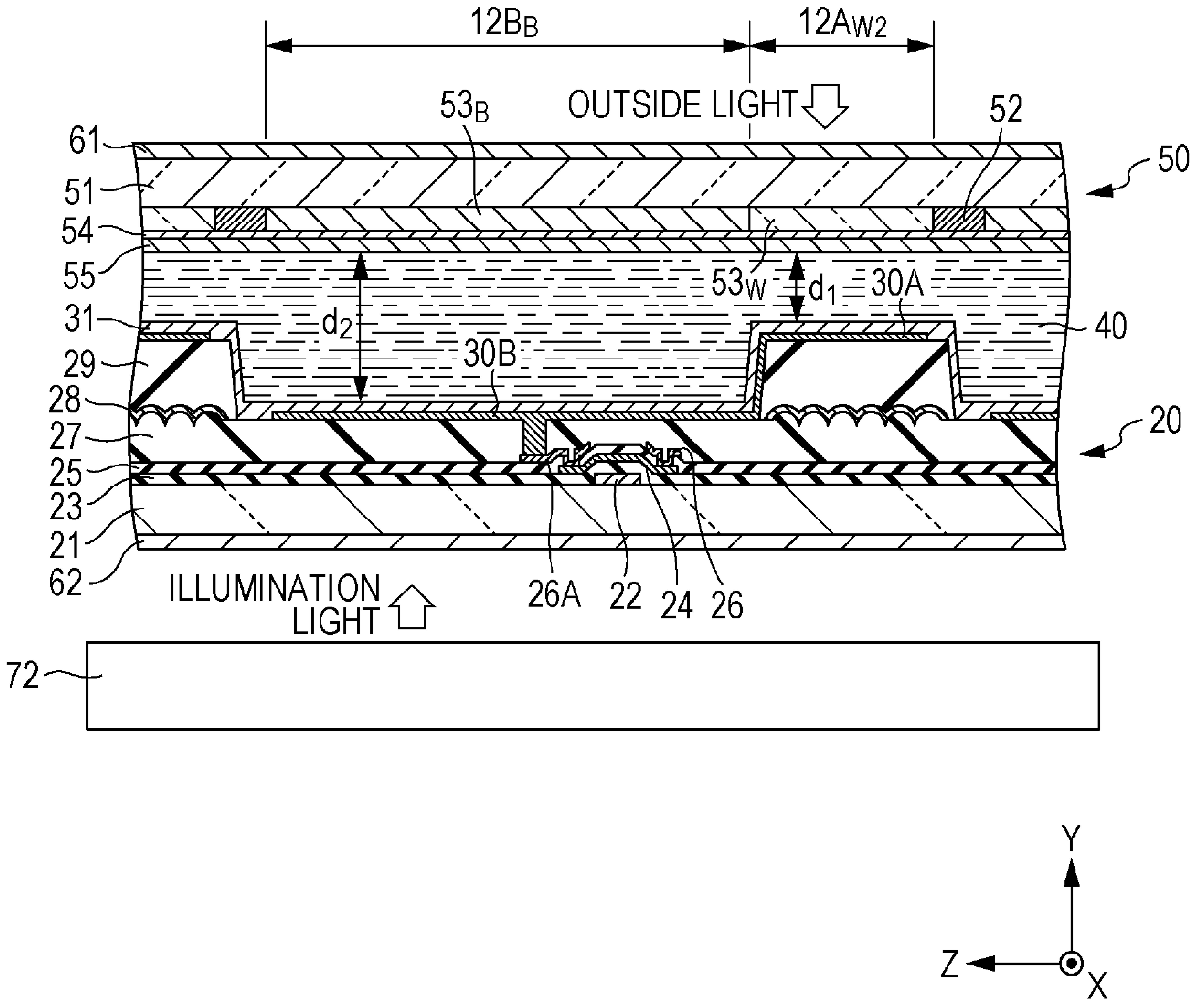

310
202
SIGNAL OUTPUT CIRCUIT
VSB
VSG
VSR
263_m
263_{3m-1}
263_{3m-2}
$12_{(m, n)}$
$12A_{W2}$
$12A_{W1}$
$12A_R$
$12B_B$
$12B_G$
$12B_R$
C_3
C_4
LC_3
LC_4
TFT
REFLECTIVE AREA
TRANSMISSIVE AREA
V_{Com}
22_n
101
SCANNING CIRCUIT

FIG. 13



Y
X
Z
IX
X
XIV
26_{3m-2}
26_{3m-1}
26_{3m}
26_{3m+1}
$12A_R$
$12A_{W1}$
$12A_{W2}$
30A
30A
30A
22_n
26A
26A
26A
30B
30B
30B
$12B_R$
$12B_G$
$12B_B$
IX
X
XIV

FIG. 14



12BB
12AW2
53B
OUTSIDE LIGHT
52
61
50
51
54
55
53W
d1
30A
31
d2
40
29
30B
28
20
27
25
23
21
62
ILLUMINATION LIGHT
26A
22
24
26
72
Y
Z
X

FIG. 15

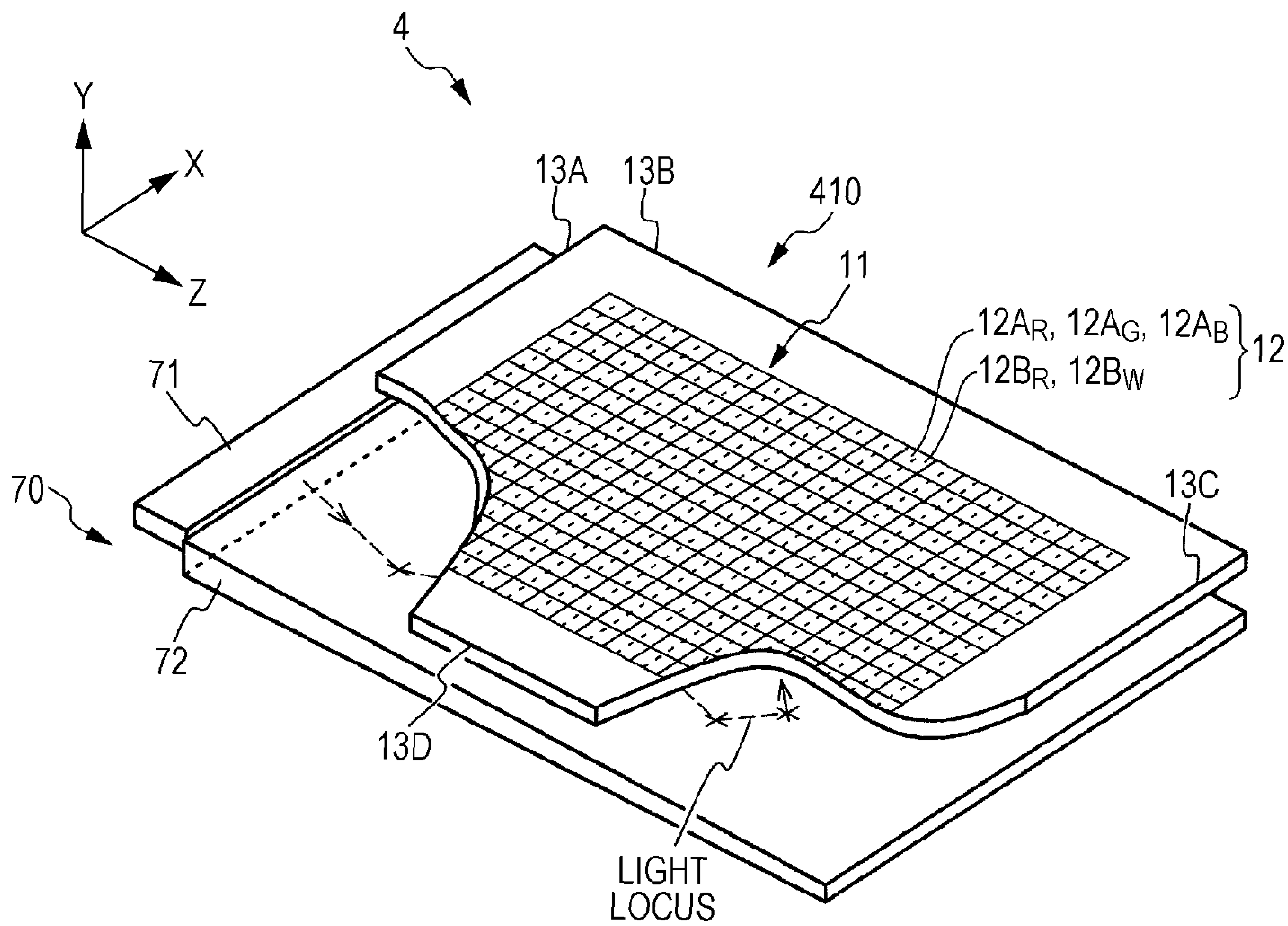

4
Y
X
Z
13A
13B
410
11
12AR, 12AG, 12AB
12BR, 12BW
12
71
70
13C
72
13D
LIGHT
LOCUS

FIG. 16

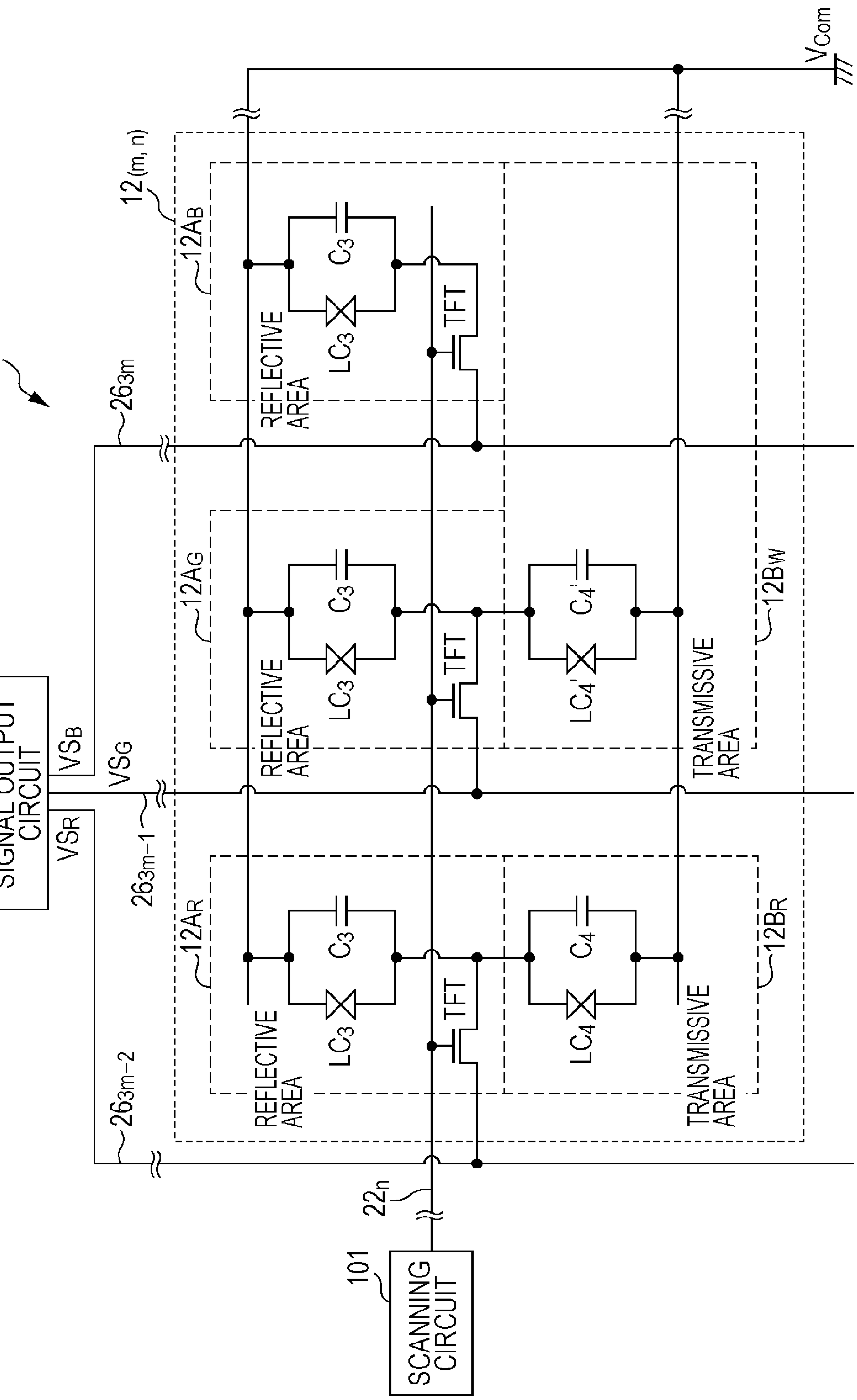
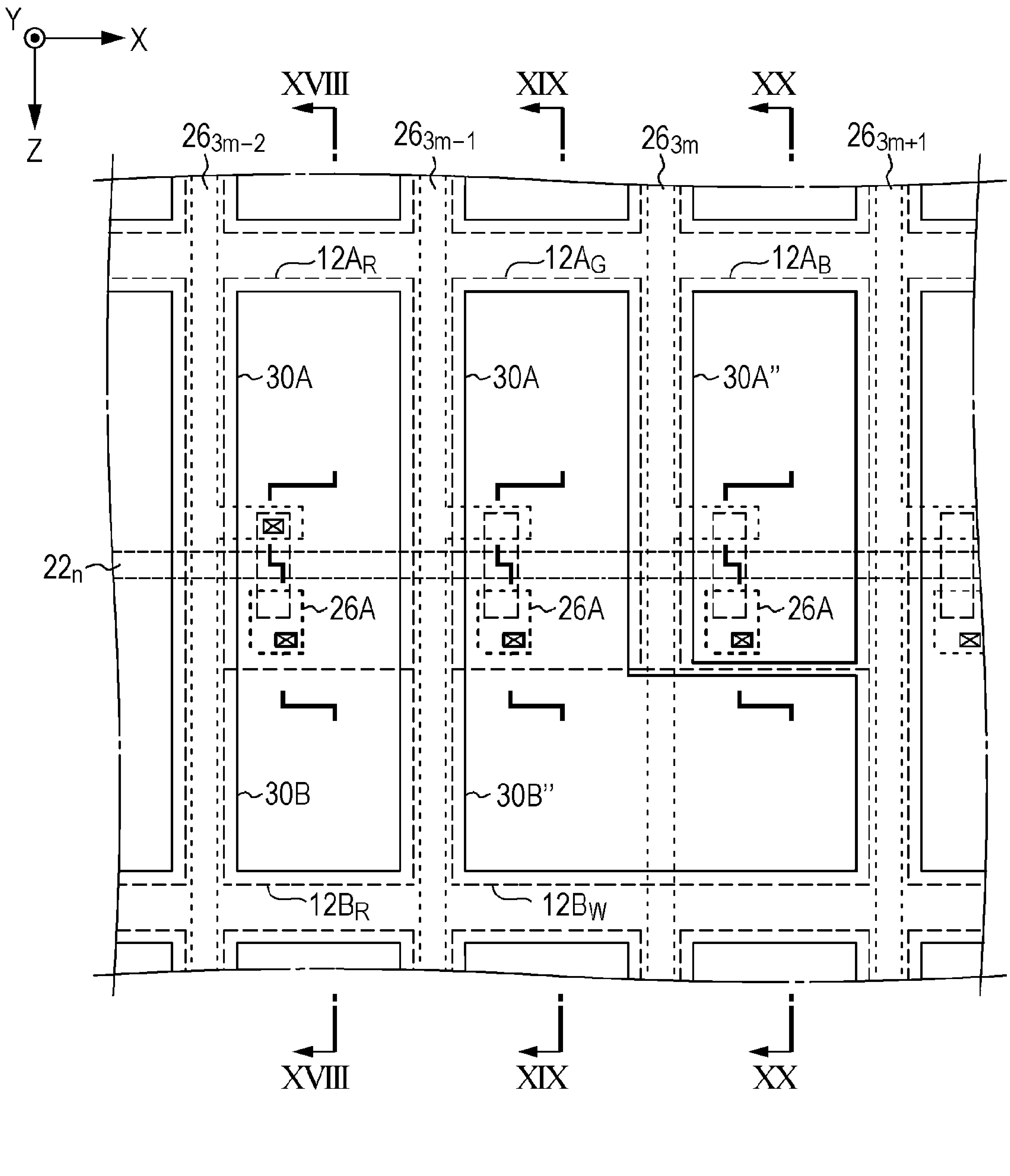
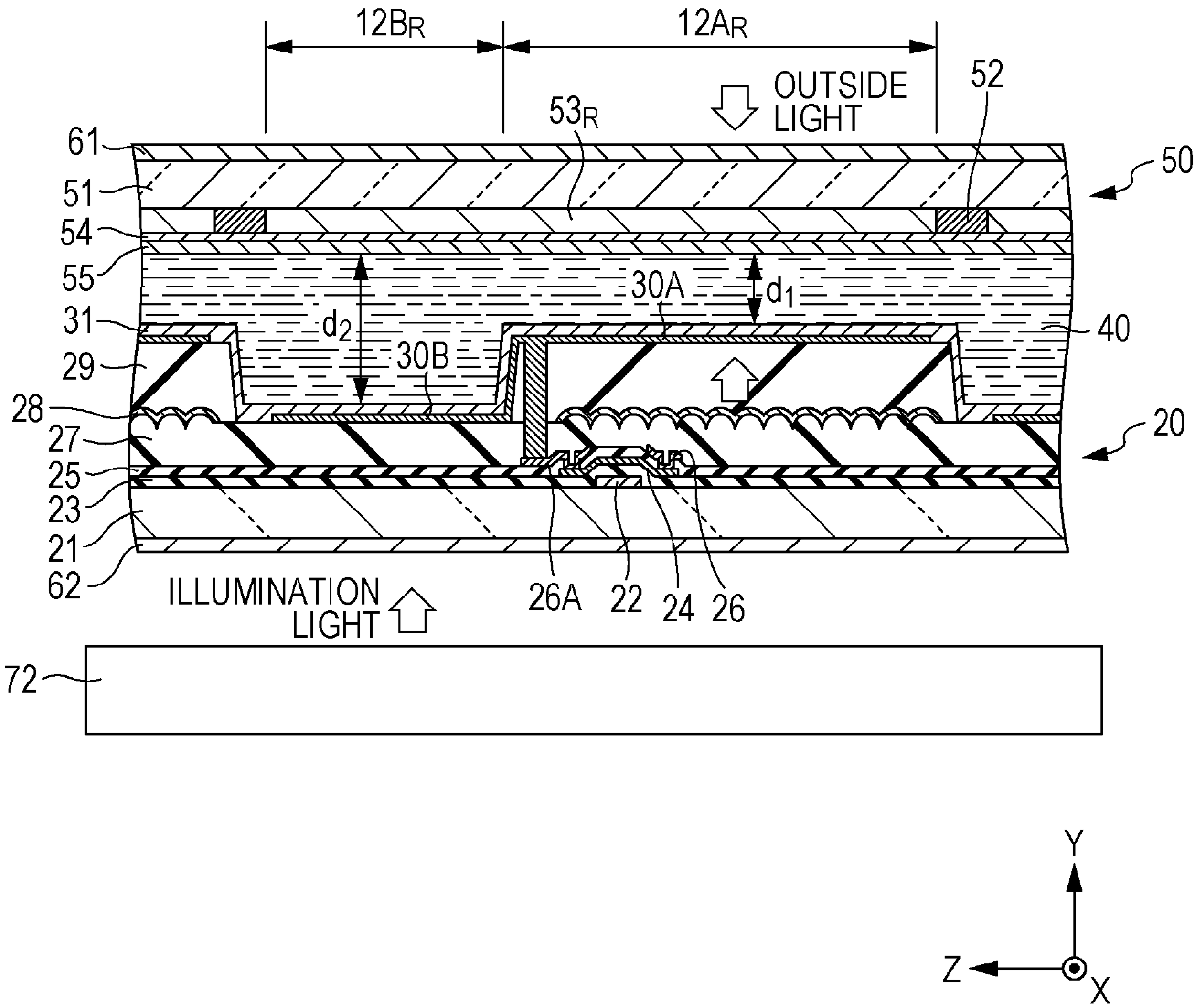

410
202
SIGNAL OUTPUT CIRCUIT
VSB
VSG
VSR
101
SCANNING CIRCUIT
22n
263m
263m−1
263m−2
12(m, n)
12AB
12AG
12AR
12BW
12BR
REFLECTIVE AREA
TRANSMISSIVE AREA
TFT
C3
LC3
C4
LC4
C4'
LC4'
VCom

FIG. 17



Y
X
Z
XVIII
XIX
XX
26_{3m-2}
26_{3m-1}
26_{3m}
26_{3m+1}
$12A_R$
$12A_G$
$12A_B$
30A
30A
30A"
22_n
26A
26A
26A
30B
30B"
$12B_R$
$12B_W$
XVIII
XIX
XX

FIG. 18



12B_R
12A_R
OUTSIDE LIGHT
52
53_R
61
51
54
55
50
d_2
30A
d_1
31
40
29
30B
28
27
20
25
23
21
62
ILLUMINATION LIGHT
26A
22
24
26
72
Y
Z
X

FIG. 19

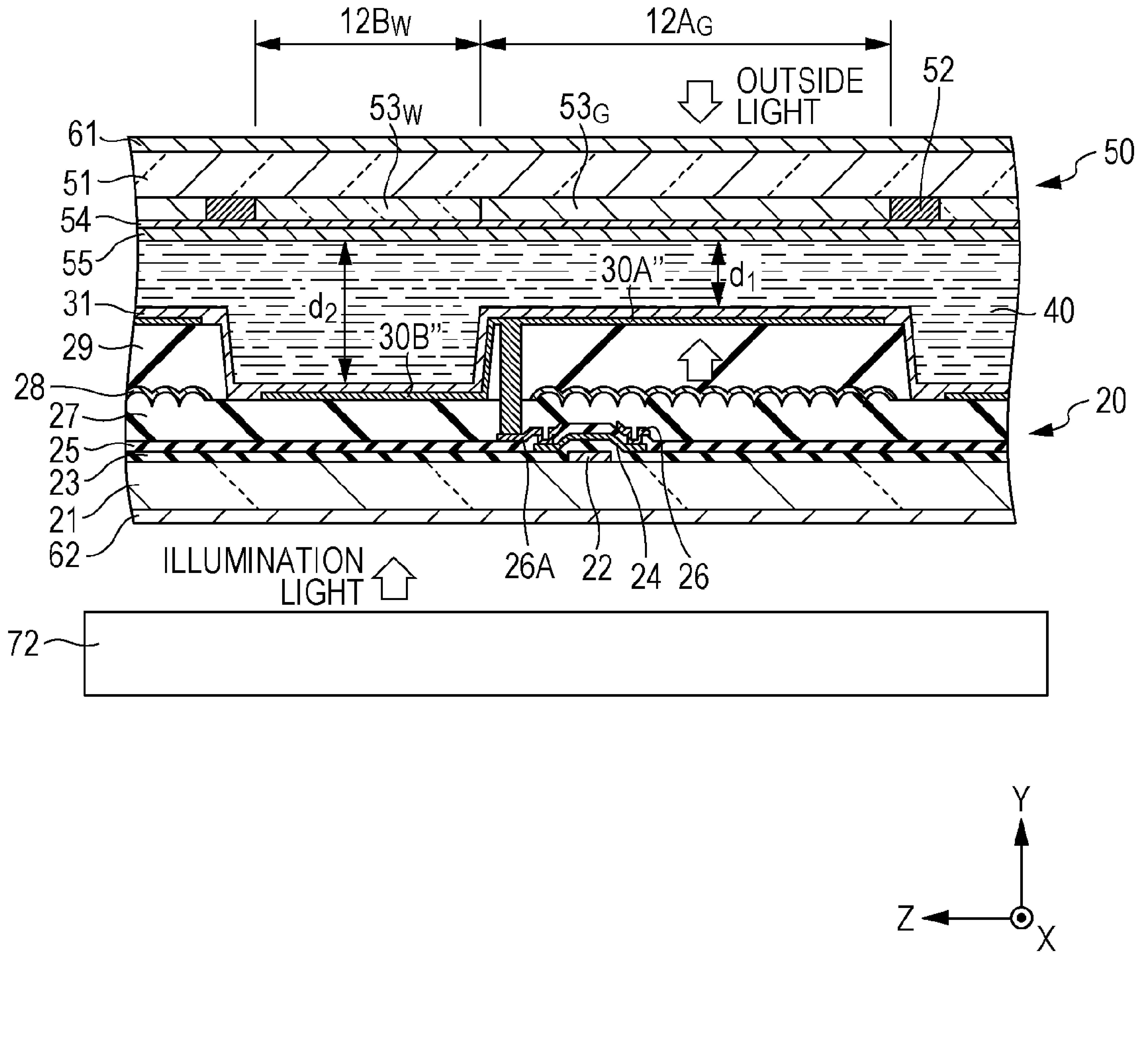

12Bw
12AG
53w
53G
OUTSIDE LIGHT
52
61
51
54
55
31
29
28
27
25
23
21
62
50
30A''
d1
d2
30B''
40
20
ILLUMINATION LIGHT
26A
22
24
26
72
Y
Z
X

FIG. 20

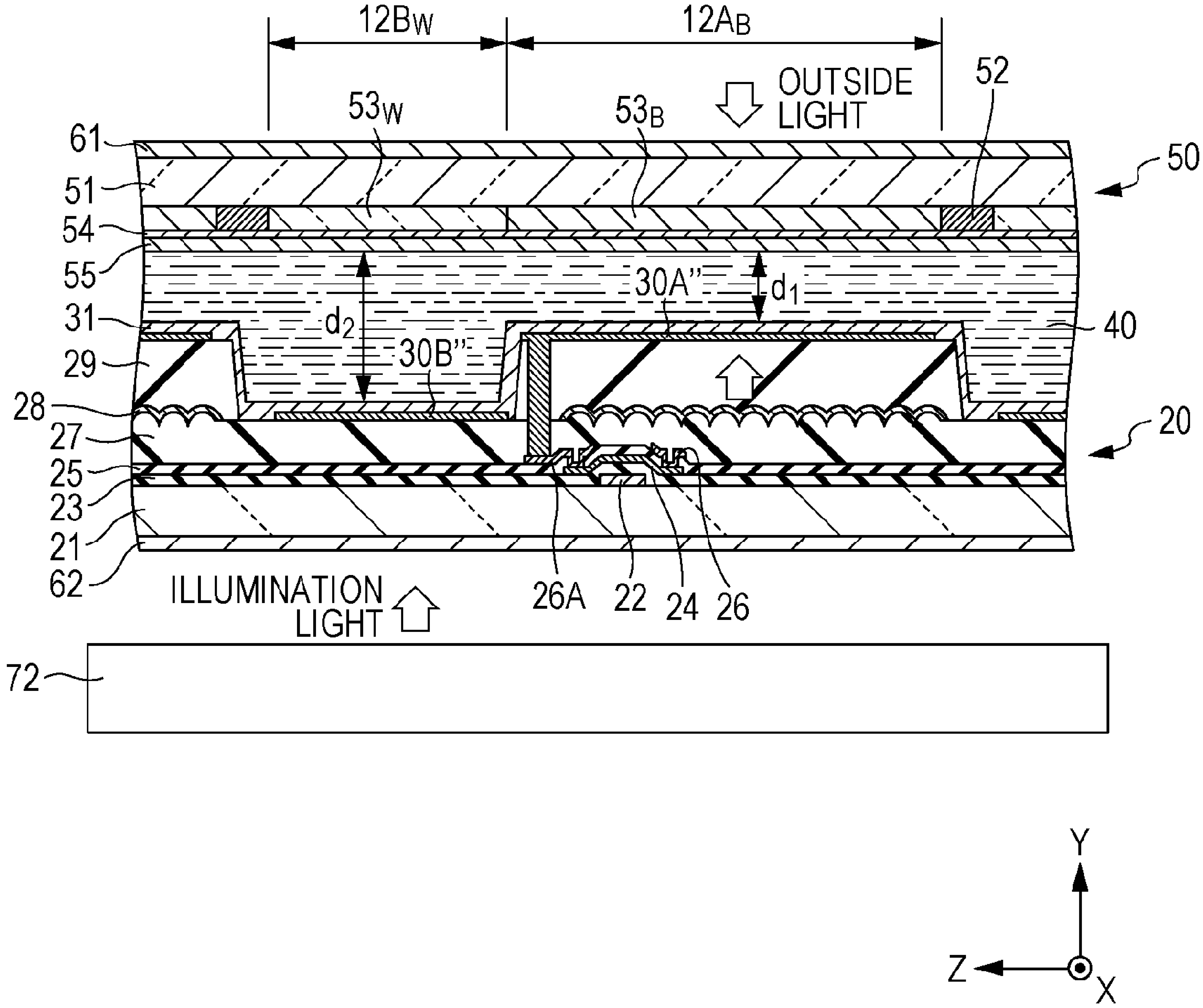

12BW
12AB
53W
53B
OUTSIDE LIGHT
52
61
51
54
55
31
29
28
27
25
23
21
62
50
40
20
d2
d1
30A''
30B''
ILLUMINATION LIGHT
26A
22
24
26
72
Y
Z
X

FIG. 21

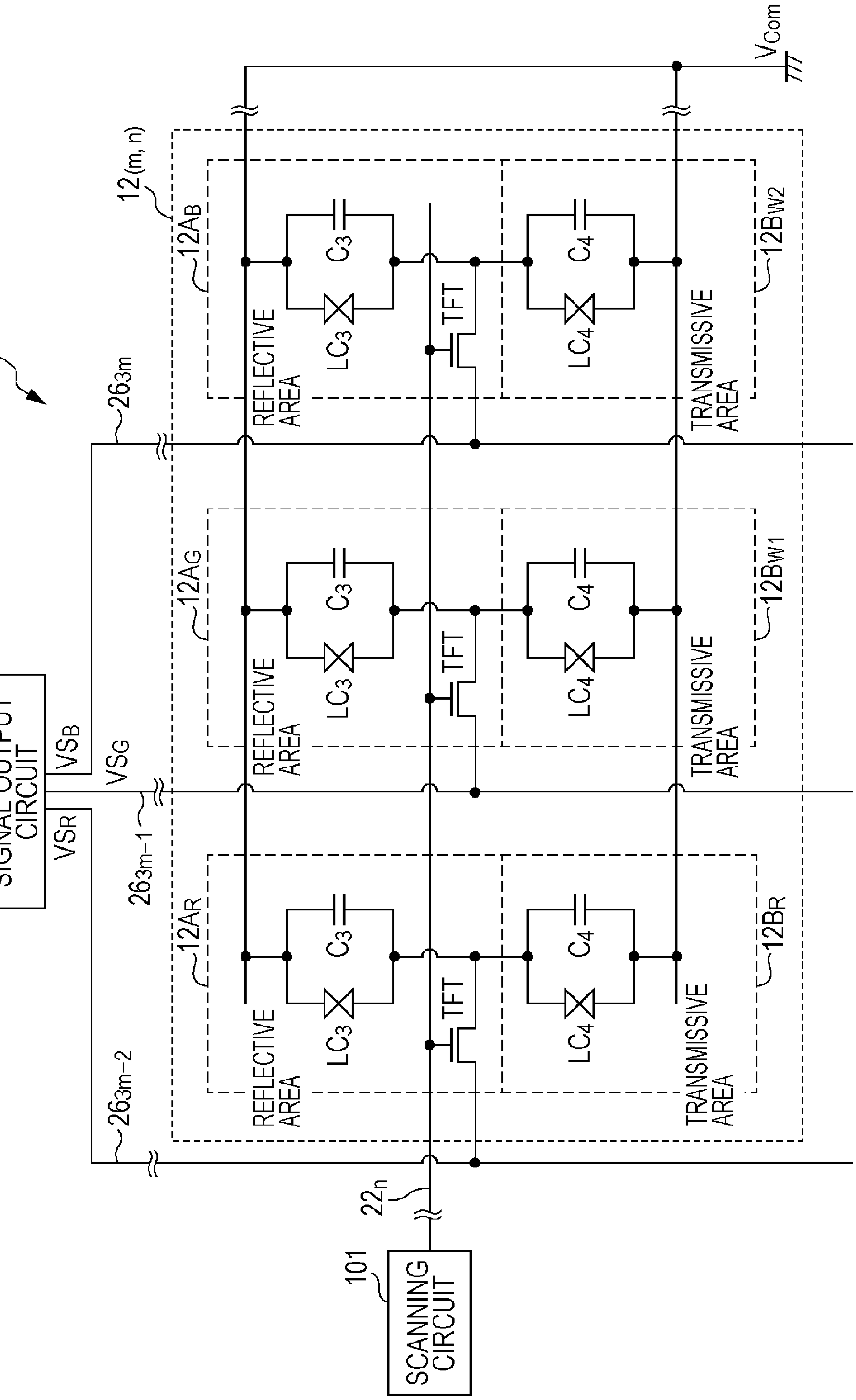

510
202
SIGNAL OUTPUT CIRCUIT
VSB
VSG
VSR
263m
263m−1
263m−2
12(m, n)
12AB
12AG
12AR
12BW2
12BW1
12BR
REFLECTIVE AREA
REFLECTIVE AREA
REFLECTIVE AREA
TRANSMISSIVE AREA
TRANSMISSIVE AREA
TRANSMISSIVE AREA
C3
C4
LC3
LC4
TFT
VCom
22n
101
SCANNING CIRCUIT

FIG. 22

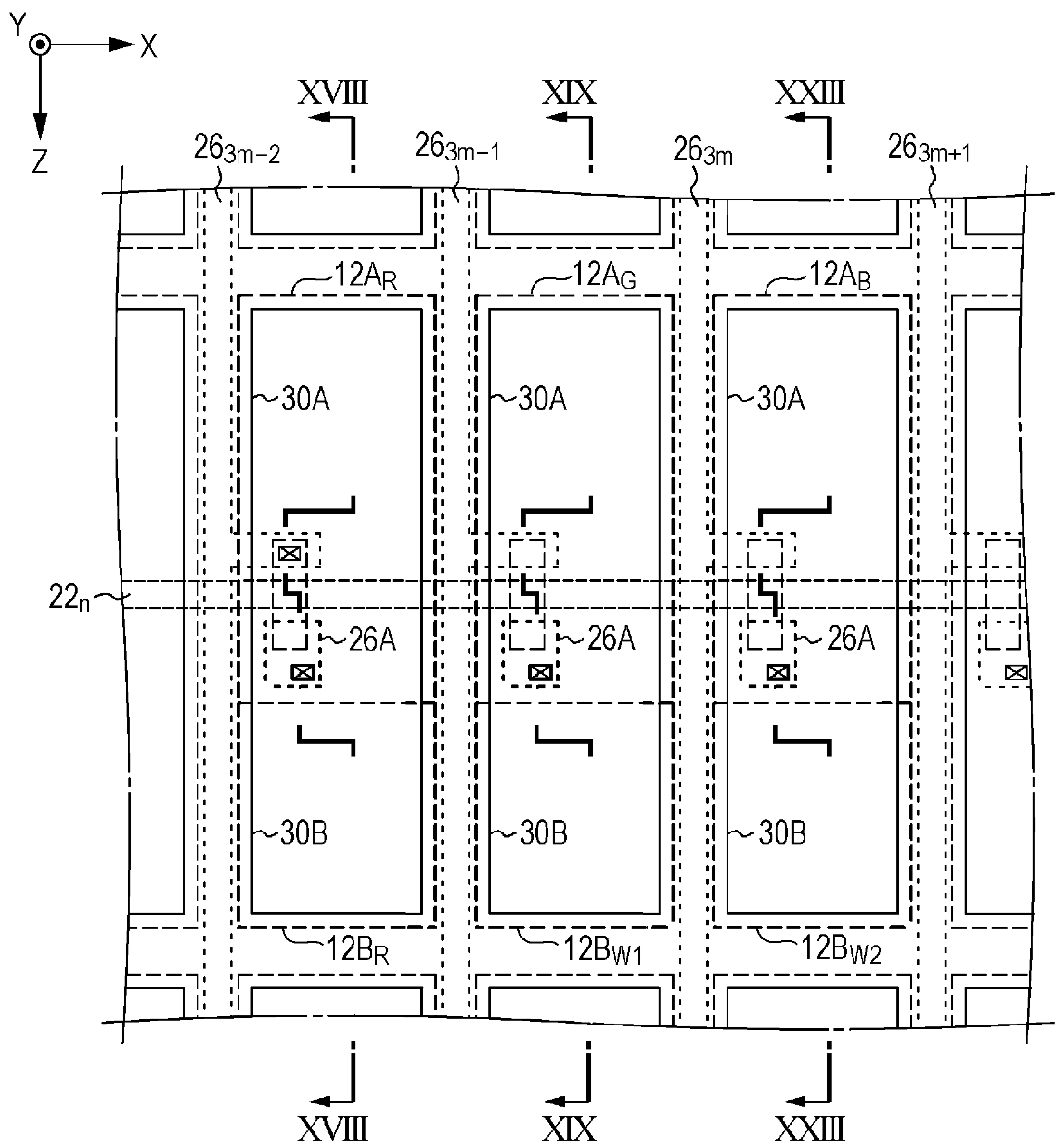
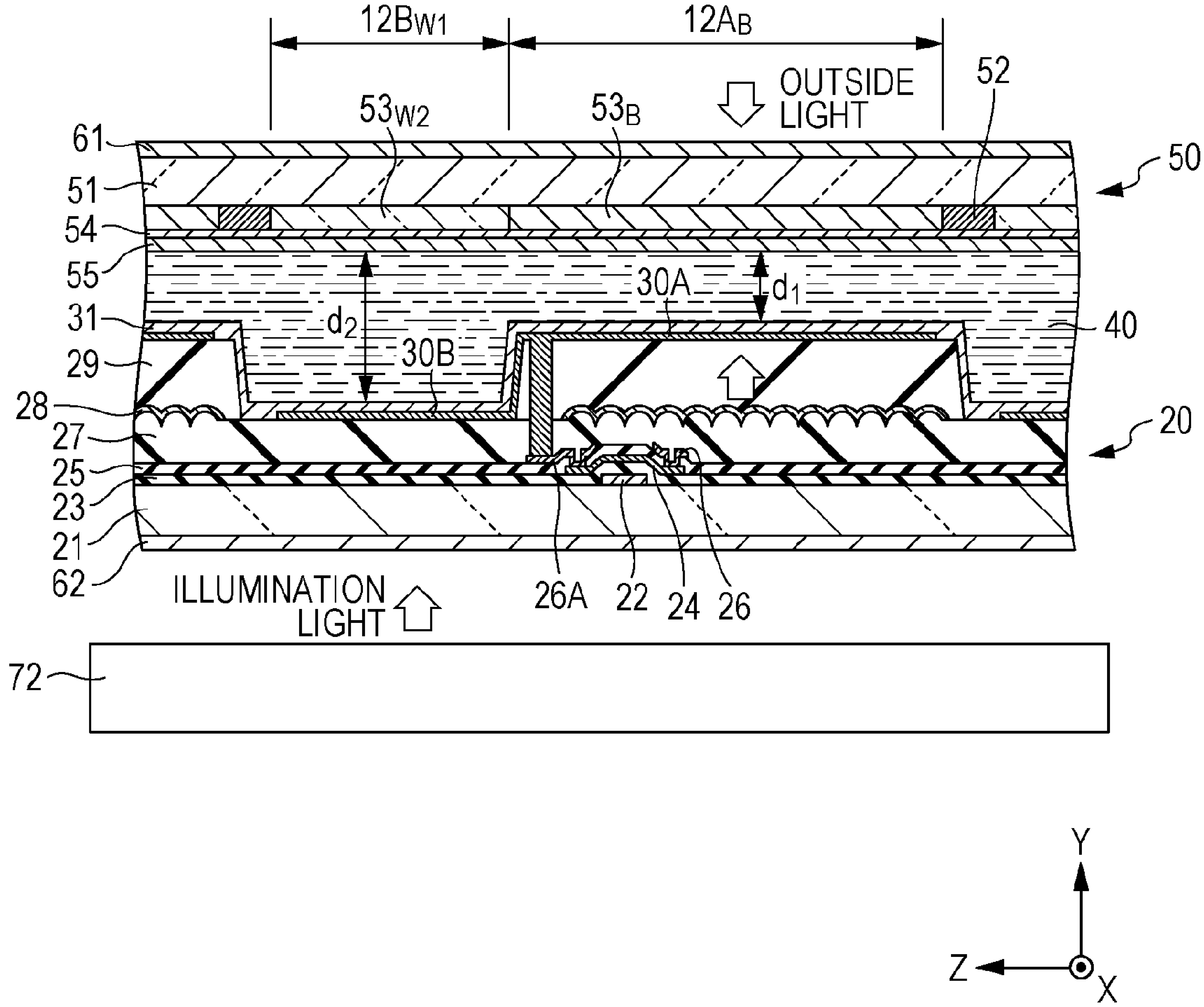

Y
X
Z
XVIII
XIX
XXIII
26_{3m-2}
26_{3m-1}
26_{3m}
26_{3m+1}
$12A_R$
$12A_G$
$12A_B$
30A
30A
30A
22_n
26A
26A
26A
30B
30B
30B
$12B_R$
$12B_{W1}$
$12B_{W2}$
XVIII
XIX
XXIII

FIG. 23



12BW1
12AB
53W2
53B
OUTSIDE LIGHT
52
61
51
54
55
50
30A
d1
d2
31
40
29
30B
28
27
20
25
23
21
62
ILLUMINATION LIGHT
26A
22
24
26
72
Y
Z
X

DISPLAY APPARATUS WITH TRANSMISSIVE AND REFLECTIVE SUBPIXELS

BACKGROUND

The present disclosure relates to a display apparatus.

Reflective display apparatuses, which display images by controlling a reflection factor of outside light, and transmissive display apparatuses, which display images by controlling a transmission factor of light from backlight disposed at a back face, have become familiar as display apparatuses, for example. Also, proposals have been made of, for example, transflective display apparatuses, which include reflective subpixels and transmissive subpixels, and function as display apparatuses having advantages of both the reflective display apparatuses and the transmissive display apparatuses (for example, refer to Japanese Patent No. 2955277).

Normally, a display apparatus performing color display includes pixels including a set of subpixels displaying the three primary colors, namely, red, green and blue. The display apparatus displays color images by controlling luminance of the individual subpixels.

SUMMARY

For example, in a transflective color display apparatus designed with priority given to display of a transmissive section, a ratio of an area occupied by reflective subpixels in a pixel is small. In this display apparatus, luminance of images reflected by outside light becomes low, and thus visibility of the images is decreased. In such a case, the visibility will be improved by suppressing color reproduction to a certain degree and displaying images having higher luminance. In this manner, depending on applications of display apparatuses, demands are growing for a display apparatus capable of displaying images having higher luminance while ensuring a certain degree of color gamut.

Accordingly, it is desirable to provide a display apparatus capable of displaying images having higher luminance while ensuring a certain degree of color gamut.

According to an embodiment of the present disclosure, there is provided a display apparatus including a display section including an array of pixels in a two-dimensional matrix, wherein each of the pixels of the display section include a pair of a subpixel displaying a first primary color, and a subpixel displaying a second primary color being different from the first primary color.

According to another embodiment of the present disclosure, there is provided a display apparatus including a transflective display section including, in a two-dimensional matrix, an array of pixels including a pair of a transmissive subpixel for displaying red color, a transmissive subpixel for displaying green color and a transmissive subpixel for displaying blue color, and a reflective subpixel for displaying red color and a reflective subpixel for displaying white color or cyan.

Further, according to another embodiment of the present disclosure, there is provided a display apparatus including a transflective display section including, in a two-dimensional matrix, an array of pixels including a pair of a reflective subpixel for displaying red color, a reflective subpixel for displaying green color and a reflective subpixel for displaying blue color, and a transmissive subpixel for displaying red color and a transmissive subpixel for displaying white color or cyan.

In a display apparatus according to an embodiment of the present disclosure, each of the pixels include a pair of a subpixel displaying a first primary color, and a subpixel displaying a second primary color being different from the first primary color. Thereby, it is possible to display images having higher luminance while ensuring a certain degree of color gamut. A display apparatus according to another embodiment of the present disclosure includes a subpixel for displaying red color and a subpixel for displaying white color or cyan as reflective subpixels. Thereby, in an image displayed by reflection of outside light, it is possible to display images having higher luminance while ensuring a certain degree of color gamut. A display apparatus according to still another embodiment of the present disclosure includes a subpixel for displaying red color and a subpixel for displaying white color or cyan as transmissive subpixels. Thereby, in an image displayed by light transmission, it is possible to display images having higher luminance while ensuring a certain degree of color gamut.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic perspective view of a display apparatus according to a first embodiment;

FIG. **2** is a schematic circuit diagram of a display section of a portion including a (m, n)-th pixel;

FIG. **3** is a schematic plan view for explaining arrangement of various components in the display section of the portion including the (m, n)-th pixel;

FIG. **4**A is a schematic sectional view of the display section taken on line IVA-IVA of FIG. **3**;

FIG. **4**B is a schematic sectional view of the display section taken on line IVB-IVB of FIG. **3**;

FIG. **5**A is a schematic xy-chromaticity diagram for explaining a color gamut in the case of using subpixels displaying red, green, and blue;

FIG. **5**B is a schematic xy-chromaticity diagram for explaining a color gamut in the case of using subpixels displaying red, and subpixels displaying white or cyan;

FIG. **6** is a schematic perspective view of a display apparatus according to a second embodiment;

FIG. **7** is a schematic circuit diagram of a display section of a portion including a (m, n)-th pixel;

FIG. **8** is a schematic plan view for explaining arrangement of various components in the display section of the portion including the (m, n)-th pixel;

FIG. **9** is a schematic sectional view of the display section taken on line IX-IX of FIG. **8**;

FIG. **10** is a schematic sectional view of the display section taken on line X-X of FIG. **8**;

FIG. **11** is a schematic sectional view of the display section taken on line XI-XI of FIG. **8**;

FIG. **12** is a schematic circuit diagram of a display section of a portion including a (m, n)-th pixel in a display apparatus according to a third embodiment;

FIG. **13** is a schematic plan view for explaining arrangement of various components in the display section of the portion including the (m, n)-th pixel;

FIG. **14** is a schematic sectional view of the display section taken on line XIV-XIV of FIG. **13**;

FIG. **15** is a schematic perspective view of a display apparatus according to a fourth embodiment;

FIG. **16** is a schematic circuit diagram of a display section of a portion including a (m, n)-th pixel;

FIG. **17** is a schematic plan view for explaining arrangement of various components in the display section of the portion including the (m, n)-th pixel;

FIG. **18** is a schematic sectional view of the display section taken on line XVIII-XVIII of FIG. **17**;

FIG. **19** is a schematic sectional view of the display section taken on line XIX-XIX of FIG. **17**;

FIG. **20** is a schematic sectional view of the display section taken on line XX-XX of FIG. **17**;

FIG. **21** is a schematic circuit diagram of a display section of a portion including a (m, n)-th pixel in a display apparatus according to a fifth embodiment;

FIG. **22** is a schematic plan view for explaining arrangement of various components in the display section of the portion including the (m, n)-th pixel; and

FIG. **23** is a schematic sectional view of the display section taken on line XXIII-XXIII of FIG. **22**.

DETAILED DESCRIPTION OF EMBODIMENTS

In the following, a description will be given of the present disclosure on the basis of embodiments with reference to the drawings. The present disclosure is not limited to the embodiments, and various numeric values and materials in the embodiments are described as an example. In the following description, a same reference numeral is given to a same component or a component having a same function, and thus a duplicated description will be omitted. In this regard, the descriptions will be given in the following order.

1. Description on display apparatus according to the present disclosure in general
2. First embodiment
3. Second embodiment
4. Third embodiment
5. Fourth embodiment
6. Fifth embodiment (the others)

Description on display apparatus according to the present disclosure in general

In a display apparatus according to an embodiment of the present disclosure, it is desirable to determine the first primary color to be a color having high chroma and brightness basically. Above all, it is desirable to determine the first primary color to be red. In this case, it is desirable to determine the second primary color to be white or cyan.

In a display apparatus according to an embodiment, which includes the above-described preferable configuration, it is possible to employ a configuration in which a subpixel displaying the first primary color is driven using a video signal for displaying red color, and a subpixel displaying the second primary color using a video signal for displaying green color. In this regard, in the present specification, "using a video signal" includes a configuration of using a signal that is produced by processing a video signal in addition to using the video signal without change. For example, it is possible to employ a configuration in which a subpixel displaying the second primary color is driven using the video signal for displaying green color without change, or to employ a configuration in which a subpixel displaying the second primary color is driven using a signal produced by processing the video signal for displaying green color, etc.

In the display apparatus according to the embodiment, which includes the above-described various preferable configurations, for the display section, it is possible to use a widespread display panel, such as a liquid-crystal display panel, an electro-luminescence display panel, a plasma display panel, an electronic paper (for example, electrophoretic type), or the like. Among these, it is desirable to employ a display section including a liquid-crystal display panel from a viewpoint of reducing weight of the display apparatus, etc. The configuration of the liquid-crystal display panel is not particularly limited. For example, the liquid-crystal display panel may be reflective type, may be transmissive type, or may be transflective type, which has advantages of both of the former two types.

In a display apparatus according to another embodiment of the present disclosure, it is possible to employ a configuration in which a transmissive subpixel for displaying red color and a reflective subpixel for displaying red color are driven using a video signal for displaying red color, a transmissive subpixel for displaying green color and a reflective subpixel for displaying white color or cyan are driven using a video signal for displaying green color, and a transmissive subpixel for displaying blue color is driven using a video signal for displaying blue color.

Alternatively, in the display apparatus according to another embodiment of the present disclosure, a pixel includes a first reflective subpixel and a second reflective subpixel for displaying white color or cyan, and thus it is possible to employ a configuration in which a transmissive subpixel for displaying red color and a reflective subpixel for displaying red color are driven using a video signal for displaying red color, a transmissive subpixel for displaying green color and a first reflective subpixel for displaying white color or cyan are driven using a video signal for displaying green color, and a transmissive subpixel for displaying blue color, and a second reflective subpixel for displaying white color or cyan are driven using a video signal for displaying blue color.

In a display apparatus according to still another embodiment of the present disclosure, it is possible to employ a configuration in which a reflective subpixel for displaying red color and a transmissive subpixel for displaying red color are driven using a video signal for displaying red color, a reflective subpixel for displaying green color and a transmissive subpixel for displaying white color or cyan are driven using a video signal for displaying green color, and a reflective subpixel for displaying blue color is driven using a video signal for displaying blue color.

Alternatively, in the display apparatus according to still another embodiment of the present disclosure, a pixel includes a first transmissive subpixel and a second transmissive subpixel for displaying white color or cyan, and thus it is possible to employ a configuration in which a reflective subpixel for displaying red color and a transmissive subpixel for displaying red color are driven using a video signal for displaying red color, a reflective subpixel for displaying green color and a first transmissive subpixel for displaying white color or cyan are driven using a video signal for displaying green color, and a reflective subpixel for displaying blue color and a second transmissive subpixel for displaying white color or cyan are driven using a video signal for displaying blue color.

In the above-described preferable configuration according to the other embodiment, or in the above-described preferable configuration according to the still other embodiment, it is possible to use a widespread transflective display panel as the display section. Above all, it is desirable to employ a display section including a transflective liquid-crystal display panel from a viewpoint of reducing weight of the display apparatus, etc. The configuration of the liquid-crystal display panel is not particularly limited.

In the case of using an illumination section irradiating light on the display section, a widespread illumination section can be used. A configuration of the illumination section is not particularly limited. In general, it is possible to configure the illumination section from a widespread member, such as a light source, a light guiding plate, or the like.

In each of the embodiments described later, an active-matrix type color-liquid-crystal display panel is used as the display section.

The liquid-crystal display panel includes, for example, a front panel including a transparent common electrode, a rear panel including a pixel electrode, and a liquid crystal material disposed between the front panel and the rear panel. In the case of a transmissive type, the pixel electrode ought to be formed by a transparent conductive material. Also, in the case of a reflective type, it is possible to form the pixel electrode by a light reflecting material. Alternatively, it is also possible to dispose a light reflecting plate independently of a pixel electrode, and to configure the pixel electrode from a transparent conductive material. This is the same in the case of a transflective type.

An operation mode of the liquid-crystal display panel is not particularly limited. For example, a configuration in which the liquid-crystal display panel is driven in a so-called TN (Twisted Nematic) mode may be employed. Alternatively, a configuration in which the liquid-crystal display panel is driven in a VA (Vertical Alignment) mode, or an IPS (In-Plane Switching) mode may be employed.

More specifically, the front panel includes, for example, a substrate made of glass, a transparent common electrode (for example, made of ITO (Indium Tin Oxide)) disposed on the inner face of the substrate, and a polarizing film disposed on the outer face of the substrate. A color filter covered by an overcoat layer made of acrylic resin or epoxy resin is disposed on the inner face of the substrate. And the front panel has a configuration in which a transparent common electrode is further formed on the overcoat layer. In this regard, an alignment film is formed on the transparent common electrode if necessary.

On the other hand, the rear panel includes, for example, a substrate made of glass, a switching element formed on the inner face of the substrate, a pixel electrode (for example, made of ITO) which is controlled to be conductive or non-conductive by the switching element. If necessary, an alignment film is formed on the whole area including the pixel electrode, and a polarizing film is disposed on the outer face of the substrate.

Various kinds of members and a liquid crystal material included in a liquid-crystal display panel can be made of widespread members and materials. For a switching element, for example, a three-terminal element, such as a thin film transistor (TFT), and a two-terminal element, such as an MIM (Metal Insulator Metal) element, a varistor element, a diode, etc., are given as examples. For example, a scanning line extending in a row direction and a signal line extending in a column direction are connected to these switching elements.

The display section is not limited to a certain shape in particular. The display section may be a horizontally long rectangle in shape, or may be a vertically long rectangle in shape. When the number of pixels, M×N, in the display section is denoted by (M, N), for example, if the display section is a horizontally long rectangle in shape, values of (M, N) are given by (640, 480), (800, 600), (1024, 768), etc., as some examples of image display resolutions. If the display section is a vertically long rectangle in shape, it is possible to exemplify the resolutions by the values that are mutually replaced with each other. However, the resolution is not limited to these values.

It is possible to configure a drive circuit that drives the display section, etc., by various circuits. It is possible to configure the drive circuit using widespread circuit elements, etc.

Various conditions described in the present specification are satisfied if the conditions are substantially met in addition to the case where the conditions are strictly met. For example, it will suffice if "red" is substantially recognized as red, and "green" is substantially recognized as green. This is the same for "blue", "white" and "cyan". Various kinds of variations that arise in design or in production are permissible.

First Embodiment

A description will be given of a display apparatus according to a first embodiment of the present disclosure.

FIG. **1** is a schematic perspective view of a display apparatus according to the first embodiment.

A display apparatus **1** includes a display section **10** including an array of pixels **12** in a two-dimensional matrix. The pixel **12** of the display section **10** includes a pair of a subpixel **12**A_R displaying a first primary color and a subpixel **12**A_W displaying a second primary color, which is different from the first primary color. In the first embodiment, the first primary color is red, and the second primary color is white.

The display section **10** includes a reflective liquid-crystal display panel. For convenience of explanation, it is assumed that a display area **11** of the display section **10** is parallel to an X-Z plane, and an image observer's side in a +Y direction. In this regard, a scanning circuit **101** and a signal output circuit **102**, which are illustrated in FIG. **2** later, are omitted to be illustrated in FIG. **1**.

The display section **10** includes a front panel on the +Y direction side in FIG. **1**, a rear panel on the −Y direction side, a liquid crystal material disposed between the front panel and the rear panel, etc. In this regard, For convenience of illustration, the display section **10** is illustrated as one piece of panel in FIG. **1**. The display section **10** is rectangular in shape, and the display area **11** on which pixels **12** are disposed in an array is also rectangular in shape. Reference numerals **13**A, **13**B, **13**C, and **13**D denote sides of the display section **10**. This is the same for display sections according to the other embodiments illustrated in FIG. **6** and FIG. **15**, which will be described later.

The display area **11** includes the array with M pieces of pixels **12** in a row direction (the X direction in the figure) and N pieces of pixels **12** in a column direction (the Z direction in the figure), namely M×N pieces of the pixels **12** in total. A pixel **12** in the m-th column (note that m=1, 2 . . . , M) and the n-th row (note that n=1, 2 . . . , N) is denoted by a (m, n)-th pixel **12** or a pixel $\mathbf{12}_{(m, n)}$. The number of pixels (M, N) of the display section **10** is (768, 1024), for example. This is the same for the display sections in the other embodiments.

In the first embodiment, a pixel **12** includes a pair of reflective subpixels **12**A_R and **12**A_W. A description will be given of details of the subpixels.

FIG. **2** is a schematic circuit diagram of a display section of a portion including a (m, n)-th pixel.

The display apparatus **1** is a display apparatus that includes N pieces of scanning lines **22**, which extend in a row direction and individual one ends of which are connected to the scanning circuit **101**, 2×M pieces of signal lines **26**, which extend in a column direction and individual one ends of which are connected to the signal output circuit **102**, and reflective subpixels **12**A_R and **12**A_W, which are connected to the individual scanning lines **22** and the individual signal lines **26** and include a transistor (TFT) operating in response to a scanning signal from the individual scanning lines **22**.

An n-th row scanning line **22** (hereinafter, sometimes denoted by a scanning line $\mathbf{22}_n$) is connected to a pixel $\mathbf{12}_{(m, n)}$. A (2×m−1)-th column signal line **26** is connected to a subpixel $12A_R$, and a (2×m)-th column signal line **26** is connected to a subpixel $12A_W$. In this regard, a notation "×" is omitted in FIG. **2**. Also, in the descriptions below, the notation "×" is sometimes omitted. For example, the (2×m)-th column signal line **26** is sometimes denoted by a signal line 26_{2m}.

Liquid crystal capacitors LC_1 and LC_2, illustrated in FIG. **2**, include a transparent common electrode disposed on the front panel, a pixel electrode disposed on the rear panel, and a liquid-crystal material layer sandwiched between the front panel and the rear panel. Also, retention capacitors C_1 and C_2 are formed by auxiliary electrodes conducted to the pixel electrodes, etc. In this regard, in the following FIG. **3** and FIG. **4**, the auxiliary electrodes are omitted to be illustrated.

Signals in accordance with a color image to be displayed are supplied to the display apparatus **1** from the outside. A video signal VS_R for displaying red color and a video signal VS_G for displaying green color are generated by a circuit, not illustrated in the figure, on the basis of the signal according to the color image. And the signal output circuit **102** drives the subpixel $12A_R$ displaying the first primary color using the video signal VS_R for displaying red color, and drives the subpixel $12A_W$ for displaying the second primary color using the video signal VS_G for displaying green color.

FIG. **3** is a schematic plan view for explaining arrangement of various components in the display section of the portion including the (m, n)-th pixel. FIG. **4**A is a schematic sectional view of the display section taken on line IVA-IVA of FIG. **3**. FIG. **4**B is a schematic sectional view of the display section taken on line IVB-IVB of FIG. **3**.

As illustrated in FIG. **3**, the subpixel $12A_W$ has a larger area than that of the subpixel $12A_R$. Basically, a preferable value of the occupancy rate ought to be selected depending on design such that an occupancy rate of the subpixel $12A_W$ in the pixel **12** becomes about 60 to 80 percent.

As illustrated in FIGS. **4**A and **4**B, the display section **10** includes a rear panel **20**, a front panel **50**, and a liquid-crystal material layer **40** sandwiched between both of the panels.

The front panel **50** includes, for example, a substrate **51** made of glass, a transparent common electrode **54** (for example, made of ITO) disposed on an inner face of the substrate **51**, and a polarizing film **61** disposed on an outer face of the substrate **51**. This is the same in the other embodiments described later.

On a liquid-crystal material layer **40** side of the substrate **51**, a black matrix **52** disposed correspondingly among subpixels adjacent to one another, a color filter disposed in an area surrounded by the black matrix **52**, a transparent common electrode **54** covering a whole area including the black matrix **52** and the color filter, and an upper alignment film **55** covering a whole area including the transparent common electrode **54** are disposed. Reference numeral 53_R in FIG. **4**A is a red color filter, and reference numeral 53_W in FIG. **4**B is a white color filter (to put it in another way, a simple transparent filter).

The rear panel **20** includes, for example, a substrate **21** made of glass, a switching element including a TFT formed on the inner face of the substrate **21**, and a pixel electrode (for example, made of ITO) which is controlled to be conductive or nonconductive by the switching element.

More specifically, a first insulating film **23** and a second insulating film **25** are formed by being laminated on the liquid-crystal material layer **40** side of the substrate **21**. A semiconductor thin film **24** forming a TFT is formed between the first insulating film **23** and the second insulating film **25**. A signal line **26** is formed on the second insulating film **25**. A tongue of the signal line **26** is connected to one of source/drain electrodes of the TFT. A pixel electrode is connected to the other of the source/drain electrodes through a conductive section **26**A. Specifically, a pixel electrode **30** is connected to the other of the source/drain electrodes in FIG. **4**A. A pixel electrode **30'** is connected to the other of the source/drain electrodes in FIG. **4**B. In this regard, the conductive section **26**A is formed, for example, by patterning at the same time of formation of the signal line **26**.

The TFT functions as a switching element operating in accordance with a signal from the scanning line **22**. On the basis of a TFT operation in accordance with a scanning signal from the scanning line **22**, a voltage in accordance with a video signal is applied to the pixel electrodes **30** and **30'** through the signal line **26** from the signal output circuit **102**.

A first interlayer insulating layer **27** is formed on the second insulating film **25**. Irregularities are formed on a surface of a part of the first interlayer insulating layer **27** corresponding to a subpixel. And, for example, a light reflecting plate **28** made by aluminum evaporation is formed on the irregularities. A second interlayer insulating layer **29** is formed on the light reflecting plate **28**, and the pixel electrodes **30** and **30'** are formed on the second interlayer insulating layer **29**. And a lower alignment film **31** covering a whole area including the pixel electrodes **30** and **30'** is disposed.

As illustrated in FIG. **3**, the pixel electrodes **30** and **30'** are formed to be rectangular in shape. As illustrated in FIG. **3**, FIG. **4**A and FIG. **4**B, and the pixel electrodes **30** and **30'** are connected to the conductive sections **26**A through a contact penetrating the insulating layers **29** and **27**, respectively.

The liquid-crystal material layer **40** is in contact with the lower alignment film **31** and the upper alignment film **55**. The alignment films **31** and **55** specifies orientation of molecular axes of the liquid crystal molecules in a state in which electric field is not impressed. And the alignment state of the liquid crystal molecules included in the liquid-crystal material layer **40** is controlled by the electric field formed between the pixel electrodes **30** and **30'** and the transparent common electrode **54**.

Thickness of the liquid-crystal material layer **40** denoted by reference numeral d_1 in FIGS. **4**A and **4**B is kept to have a predetermined value by a spacer, etc., which is not illustrated in the figure. The liquid-crystal material layer **40** is controlled to have an intensity of a quarter-wave plate in accordance with an applied voltage.

For example, it is assumed that a polarizing axis of the polarizing film **61** has an angle of 135 degrees with respect to the X-axis. Outside light passes through the polarizing film **61**, and becomes linearly polarized light having an angle of 135 degrees with respect to the X-axis to enter into the liquid-crystal material layer **40**.

When the liquid-crystal material layer **40** functions as a quarter-wave plate, outside light passes through the liquid-crystal material layer **40** to become clockwise circularly polarized light. Next, the light is reflected by the light reflecting plate **28**, and becomes counterclockwise circularly polarized light. Further, the light passes through the liquid-crystal material layer **40** to become linearly polarized light having an angle of 45 degrees, and enters into the polarizing film **61**. The polarizing direction of the light incident on the polarizing film **61** is perpendicular to the polarizing axis of the polarizing film **61**, and thus the light is not emitted to an observer's side. Thereby, the luminance of the pixel **12** becomes a low state.

On the other hand, when the liquid-crystal material layer **40** functions simply as a transparent layer, outside light passes the liquid-crystal material layer **40**, and then is reflected by the light reflecting plate **28**. Further, the light passes through the liquid-crystal material layer **40**, and enters into the polarizing film **61** as linearly polarized light having an angle of 135 degrees without change. The polarizing direction of the light incident on the polarizing film **61** matches the polarizing axis of the polarizing film **61**, and thus the light is emitted to the observer's side. Thereby, the luminance of the pixel **12** becomes a high state.

The liquid-crystal material layer **40** is controlled to have an intensity of a function of the quarter-wave plate in accordance with the applied voltage. A voltage in accordance with the video signal is applied to the pixel electrodes **30** and **30'** through the signal line **26** from the signal output circuit **102**, thus a reflection factor of the outside light is controlled, and thereby an image is displayed.

Next, a description will be given of color gamut and luminance of an image displayed on the display apparatus **1**.

FIG. **5**A is a schematic xy-chromaticity diagram for explaining a color gamut in the case of using subpixels displaying red, green, and blue. FIG. **5**B is a schematic xy-chromaticity diagram for explaining a color gamut in the case of using subpixels displaying red, and subpixels displaying white or cyan.

When subpixels displaying red, green and blue are used, it is possible to display colors in an area of a triangle having vertices denoted by reference numerals R, G, and B illustrated in FIG. **5**A from additive mixture of colors. On the other hand, when subpixels displaying red and subpixels displaying white are used, it is possible to display colors in a line segment connecting points denoted by reference numerals W and R in FIG. **5**B from additive mixture of colors. In this regard, in the case of a configuration in which the color filter $\mathbf{53}_W$ illustrated in FIG. **4**B is replaced by a color filter for displaying cyan, it is possible to display colors in a line segment connecting points denoted by reference numerals C and R illustrated in FIG. **5**B from additive mixture of colors. In this regard, as for colors recognized by additive mixture of two colors, a description has been given, for example in, Takayanagi Kenjiro, "Method of reproducing color by two-color method", Television, Nikkan Kogyo Shinbunsha, Mar. 1, 1960, Vol. 14, No. 3, 111-116, 137.

When subpixels displaying red, green and blue are used, only light in a specific wavelength range is used among outside light incident on the subpixels, and thus light use efficiency is low. In contrast, in the display apparatus **1**, a large portion of the pixel **12** is occupied by the subpixel **12**W, and further, the subpixel **12**W uses outside light without change for displaying. Accordingly, light use efficiency is high, and thus it is possible to display an image having higher luminance. Although light use efficiency is lowered a little, this is the same for the configuration in which the color filter $\mathbf{53}_W$ is replaced by the color filter for displaying cyan.

And as described above, in the display apparatus **1**, it is possible to display colors in a line segment connecting points denoted by reference numerals W and R in FIG. **5**B from additive mixture of colors. Also, in the configuration in which the color filter $\mathbf{53}_W$ is replaced by the color filter for displaying cyan, it is possible to display colors in a line segment connecting points denoted by reference numerals C and R illustrated in FIG. **5**B. Accordingly, it is possible to ensure a certain range of color gamut.

Second Embodiment

A description will be given of a display apparatus according to a second embodiment of the present disclosure.

FIG. **6** is a schematic perspective view of a display apparatus according to the second embodiment.

A display apparatus **2** includes a transflective display section **210** including an array of pixels **12** in a two-dimensional matrix. The pixel **12** includes a pair of one of a transmissive subpixel $\mathbf{12}\mathrm{B}_R$ for displaying red color, a transmissive subpixel $\mathbf{12}\mathrm{B}_G$ for displaying green color and a transmissive subpixel $\mathbf{12}\mathrm{B}_R$ for displaying blue color, and one of a reflective subpixel $\mathbf{12}\mathrm{A}_R$ for displaying red color and a reflective subpixel $\mathbf{12}\mathrm{A}_W$ for displaying white color.

The display apparatus **2** includes an illumination section **70** emitting light from a back face of the display section **10**. The illumination section **70** includes a light guiding plate **72** which is disposed opposed to the back face of the display section **210**, and a light source **71** which is disposed opposed to an end face of the light guiding plate **72**, and, for example, includes a cold cathode fluorescent lamp. The light guiding plate **72** is substantially rectangular in shape.

Normally, intensity of light reaching the display section **10** has a tendency to become weaker as a distance from the light source **71** becomes larger. In order to cancel this tendency, the light guiding plate **72** is wedge-shaped. The light source **71** is disposed opposed to an end face of a side **13**A of the light guiding plate **72**. Thickness of the light guiding plate **72** becomes gradually smaller from the side **13**A toward the side **13**C. An incident angle of light that entered into the light guiding plate **72** toward a face of the display section **210** becomes smaller each time the light is totally reflected in the light guiding plate **72**. Accordingly, the longer the distance from the light source **71**, the smaller becomes an incident angle of the light that travels in the light guiding plate **72** toward the face of the display section **210**, and thus the light becomes easier to go through the display section **210**. Thereby, the above-described tendency is canceled, and thus it is possible to illuminate the display section **210** with a certain intensity regardless of the distance from the light source **71**.

The display section **210** includes a transflective liquid-crystal display panel. For convenience of explanation, it is assumed that a display area **11** of the display section **210** is parallel to an X-Z plane, and an observer's side of an image is in +Y direction. A scanning circuit **101** and a signal output circuit **202**, which will be illustrated in FIG. **7** later, are omitted to be illustrated in FIG. **6**. These are the same in the other embodiments described later.

A description will be given of details of the subpixels according to the second embodiment.

FIG. **7** is a schematic circuit diagram of a display section of a portion including a (m, n)-th pixel.

The display apparatus **2** is a display apparatus that includes N pieces of scanning lines **22**, which extend in a row direction and individual one ends of which are connected to the scanning circuit **101**, 3×M pieces of signal lines **26**, which extend in a column direction and individual one ends of which are connected to the signal output circuit **202**, and subpixels, which are connected to the individual scanning lines **22** and the individual signal lines **26** and include a transistor (TFT) operating in response to a scanning signal from the individual scanning lines **22**. This is the same for the other embodiments described later.

An n-th row scanning line $\mathbf{22}_n$ is connected to a pixel $\mathbf{12}_{(m,n)}$. A (3×m−2)-th column signal line $\mathbf{26}_{3m-2}$ is connected to a subpixel $\mathbf{12}\mathrm{A}_R$ and a subpixel $\mathbf{12}\mathrm{B}_R$, a (3×m−1)-th column signal line $\mathbf{26}_{3m-1}$ is connected to a subpixel $\mathbf{12}\mathrm{A}_W$ and a subpixel $\mathbf{12}\mathrm{B}_G$, and a (3×m)-th column signal line $\mathbf{26}_{3m}$ is connected to a subpixel $\mathbf{12}\mathrm{B}_R$.

Liquid crystal capacitors LC_3, LC_3' and LC_4, illustrated in FIG. **7**, include a transparent common electrode disposed on the front panel, a pixel electrode disposed on the rear panel, and a liquid-crystal material layer sandwiched between the front panel and the rear panel. Also, retention capacitors C_3,

C_3' and C_4 are formed by auxiliary electrodes conducted to the pixel electrodes, etc. In this regard, in the following FIG. **8** to FIG. **11**, the auxiliary electrodes are omitted to be illustrated.

Signals in accordance with a color image to be displayed are supplied to the display apparatus **2** from the outside. A video signal VS_R for displaying red color, a video signal VS_G for displaying green color and a video signal VS_B for displaying blue color are generated by a circuit, not illustrated in the figure, on the basis of the signal according to the color image. And the signal output circuit **202** drives a transmissive subpixel **12**B_R for displaying red color and a reflective subpixel **12**A_R for displaying red color using the video signal VS_R for displaying red color. The signal output circuit **202** drives the transmissive subpixel **12**B_G for displaying green color and the reflective subpixel **12**A_W for displaying white color using the video signal VS_G for displaying green color. And the signal output circuit **202** drives a transmissive subpixel **12**B_B for displaying blue color using a video signal VS_B for displaying blue color.

FIG. **8** is a schematic plan view for explaining arrangement of various components in the display section of the portion including the (m, n)-th pixel. FIG. **9** is a schematic sectional view of the display section taken on line IX-IX of FIG. **8**. FIG. **10** is a schematic sectional view of the display section taken on line X-X of FIG. **8**. FIG. **11** is a schematic sectional view of the display section taken on line XI-XI of FIG. **8**.

As illustrated in FIG. **8**, etc., a larger portion of a pixel **12** is occupied by a transmissive subpixel in the display apparatus **2** (transmissiveness is emphasized in design). The display apparatus **2** has a configuration in which transmissive display is normally performed by additive mixture of the three primary colors, and reflective display is performed with higher luminance while ensuring a certain degree of color gamut.

The configuration of a black matrix **52**, illustrated in FIG. **9** to FIG. **11**, is the same as the configuration described in the first embodiment. A color filter is disposed in an area surrounded by the black matrix **52**. And a transparent common electrode **54** covering a whole area including the black matrix **52** and the color filter, and an upper alignment film **55** covering a whole area including the transparent common electrode **54** are disposed. Reference numeral **53**$_R$ illustrated in FIG. **9** denotes a red filter, reference numeral **53**$_G$ illustrated in FIG. **10** denotes a green filter, and reference numeral **53**$_B$ illustrated in FIG. **11** denotes a blue filter. Also, reference numeral **53**$_w$ illustrated in FIG. **10** and FIG. **11** denotes a white filter.

The rear panel **20** includes, for example, a substrate **21** made of glass, a switching element including a TFT formed on the inner face of the substrate **21**, and a pixel electrode (for example, made of ITO) which is controlled to be conductive or nonconductive by the switching element.

In this regard, a display apparatus according to the second embodiment includes a polarizing film **62** disposed on an outer face of the substrate **21** unlike the first embodiment. Also, in the display apparatus according to the second embodiment, the second interlayer insulating layer **29** and the light reflecting plate **28** on a potion corresponding to the transmissive subpixel are removed.

A polarizing axis of the polarizing film **62** has an angle of 135 degrees with respect to the X-axis. And, thickness denoted by reference numeral d_2 in FIG. **9** to FIG. **11** is set to be twice the thickness denoted by reference numeral d_1. The liquid-crystal material layer **40** of a portion corresponding to the reflective subpixel is controlled to have a function of a quarter-wave plate in accordance with an applied voltage. Also, the liquid-crystal material layer **40** of a portion corresponding to the transmissive subpixel is controlled to have a function of a half-wave plate in accordance with an applied voltage.

Operation of the reflective subpixel is the same as that described in the first embodiment. A description will be given of operation on the transmissive subpixel.

Illumination light from the light guiding plate **72** passes through the polarizing film **62** to become linearly polarized light having an angle of 135 degrees with reference to the X-axis, and enters into the liquid-crystal material layer **40**. When the liquid-crystal material layer **40** of the portion corresponding to the transmissive subpixel functions as a half-wave plate, the illumination light from the light guiding plate **72** passes through the liquid-crystal material layer **40** to become linearly polarized light having an angle of 45 degrees, and enters into the polarizing film **61**. The polarizing direction of the light incident on the polarizing film **61** is perpendicular to the polarizing axis of the polarizing film **61**, and thus the light is not emitted to an observer's side. Thereby, the luminance of the pixel **12** becomes a low state.

On the other hand, when the liquid-crystal material layer **40** of the portion corresponding to the transmissive subpixel functions simply as a transparent layer, the illumination light from the light guiding plate **72** enters into the polarizing film **61** as linearly polarized light having an angle of 135 degrees without change. The polarizing direction of the light incident on the polarizing film **61** matches the polarizing axis of the polarizing film **61**, and thus the light is emitted to the observer's side. Thereby, the luminance of the pixel **12** becomes a high state.

The liquid-crystal material layer **40** of the portion corresponding to the transmissive subpixel is controlled to have an intensity of a function of a half-wave plate in accordance with the applied voltage. A voltage in accordance with the video signal is applied to the pixel electrodes through the signal line **26** from the signal output circuit **202**, thus a transmission factor of the luminance light is controlled, and thereby an image is displayed.

The TFT functions as a switching element operating in accordance with a signal from the scanning line **22**. As illustrated in FIG. **9**, the pixel electrode **30**B of the subpixel **12**B_R and the pixel electrode **30**A of the subpixel **12**A_R are integrally formed. On the basis of a TFT operation in accordance with a scanning signal from the scanning line **22**, a voltage in accordance with a video signal VS_R is applied to these pixel electrodes through the signal line **26** from the signal output circuit **202**.

Also, as illustrated in FIG. **10**, a pixel electrode **30**B of the subpixel **12**B_G and a pixel electrode **30**A' of the subpixel **12**A_W are integrally formed. On the basis of a TFT operation in accordance with a scanning signal from the scanning line **22**, a voltage in accordance with a video signal VS_G is applied to these pixel electrodes through the signal line **26** from the signal output circuit **202**.

On the other hand, as illustrated in FIG. **11**, a pixel electrode **30**B' of the subpixel **12**B_G is formed independently of the pixel electrode **30**A' of the subpixel **12**A_W. On the basis of a TFT operation in accordance with a scanning signal from the scanning line **22**, a voltage in accordance with a video signal VS_B is applied to the pixel electrode **30**B' through the signal line **26** from the signal output circuit **202**.

And as illustrated in FIG. **8**, the pixel electrode **30**A' illustrated in FIG. **11** and the pixel electrode **30**A' illustrated in FIG. **10** are integrally formed. Accordingly, as described with reference to FIG. **10**, a voltage in accordance with the video signal VS_G is applied to the pixel electrode **30**A' illustrated in FIG. **11**.

Next, a description will be given of color gamut and luminance of an image displayed on the display apparatus **2**.

For an image based on the transmissive subpixels **12**B_R, **12**B_G and **12**B_B, it is possible to display colors in an area of a triangle having vertices denoted by reference numerals R, G, and B illustrated in FIG. **5**A from additive mixture of colors. On the other hand, for an image based on the reflective subpixel **12**A_R and **12**A_W, it is possible to display colors in a line segment connecting points denoted by reference numerals W and R in FIG. **5**B from additive mixture of colors. In this regard, in the case of a configuration in which the color filter **53**$_W$ illustrated in FIGS. **10** and **11** is replaced by a color filter for displaying cyan, it is possible to display colors in a line segment connecting points denoted by reference numerals C and R illustrated in FIG. **5**B from additive mixture of colors.

Accordingly, it is possible for the display apparatus **2** to display a favorable image by additive mixture of the three primary colors at the time of operating as a transmissive type, and to display images having higher luminance while ensuring a certain degree of color gamut at the time of operating as a reflective type.

Third Embodiment

A description will be given of a display apparatus according to a third embodiment of the present disclosure. In the third embodiment, the configuration of the reflective subpixels for displaying white color is different from the second embodiment.

In a schematic perspective view of a display apparatus according to the third embodiment, the subpixels **12**A_W illustrated in FIG. **6** ought to be changed for subpixels **12**A_{W1} and **12**A_{W2}, the display section **210** ought to be changed for a display section **310**, and the display apparatus **2** ought to be changed for a display apparatus **3**.

In the display section **310**, a pixel **12** includes a first reflective subpixel and a second reflective subpixel for displaying white color.

A description will be given of details of the subpixels according to the third embodiment.

FIG. **12** is a schematic circuit diagram of a display section of a portion including a (m, n)-th pixel according to the third embodiment.

A scanning line **22**$_n$ of an n-th row is connected to a pixel **12** (m, n). A signal line **26**$_{3m-2}$ of a (3×m−2)-th column is connected to a subpixel **12**A_R and a subpixel **12**B_R. A signal line **26**$_{3m-1}$ of a (3×m−1)-th column is connected to a subpixel **12**A_{W1} and a subpixel **12**B_G. A signal line **26**$_{3m}$ of a (3×m)-th column is connected to a subpixel **12**A_{W2} and a subpixel **12**B_B.

The description has been given of the liquid crystal capacitors LC_3 and LC_4, and the retention capacitors C_3 and C_4, illustrated in FIG. **12**, in the second embodiment with reference to FIG. **7**, and thus the description thereof will be omitted.

Signals in accordance with a color image to be displayed are supplied to the display apparatus **3** from the outside. A video signal VS_R for displaying red color, a video signal VS_G for displaying green color and a video signal VS_B for displaying blue color are generated by a circuit, not illustrated in the figure, on the basis of the signal according to the color image. And the signal output circuit **202** drives a transmissive subpixel **12**B_R for displaying red color and a reflective subpixel **12**A_R for displaying red color using the video signal VS_R for displaying red color. The signal output circuit **202** drives a transmissive subpixel **12**B_G for displaying green color and a first reflective subpixel **12**A_{W1} for displaying white color using a video signal VS_G for displaying green color. And the signal output circuit **202** drives a transmissive subpixel **12**B_B for displaying blue color and a second reflective subpixel **12**A_{W2} for displaying white color using a video signal VS_B for displaying blue color.

FIG. **13** is a schematic plan view for explaining arrangement of various components in the display section of the portion including the (m, n)-th pixel.

FIG. **14** is a schematic sectional view of the display section taken on line XIV-XIV of FIG. **13**. In this regard, a schematic sectional view of the display section taken on line IX-IX of FIG. **13** is the same as that in FIG. **9**. Also, a schematic sectional view of the display section taken on line X-X of FIG. **13** ought to be obtained by changing reference numeral **12**A_W for reference numeral **12**A_{W1} in FIG. **10**.

Operation of the display apparatus **3** is the same as described in the second embodiment except that a reflective subpixel **12**A_{W2} for white color is driven by the video signal VS_B for displaying blue color.

As illustrated in FIG. **8**, in the display section **210** according to the second embodiment, it is necessary that the individual pixel electrodes are different in planar shape. In contrast, in the display section **310** according to the third embodiment, it is possible for the individual pixel electrodes to have a same planar shape. Accordingly, the third embodiment has an advantage in that the display section **310** is easy to manufacture.

Fourth Embodiment

A description will be given of a display apparatus according to a fourth embodiment of the present disclosure.

FIG. **15** is a schematic perspective view of a display apparatus according to a fourth embodiment.

A display apparatus **4** includes a transflective display section **410** including an array of pixels **12** in a two-dimensional matrix. The pixel **12** includes a pair of one of a reflective subpixel **12**A_R for displaying red color, a reflective subpixel **12**A_G for displaying green color and a reflective subpixel **12**A_B for displaying blue color, and one of a transmissive subpixel **12**B_R for displaying red color and a transmissive subpixel **12**B_W for displaying white color. The display section **410** is made of a transflective liquid-crystal display panel.

A description will be given of details of the subpixels according to the fourth embodiment.

FIG. **16** is a schematic circuit diagram of a display section of a portion including a (m, n)-th pixel.

An n-th row scanning line **22**$_n$ is connected to a pixel **12**$_{(m, n)}$. A (3×m−2)-th column signal line **26**$_{3m-2}$ is connected to the subpixel **12**A_R and the subpixel **12**B_R, a (3×m−−1)-th column signal line **26**$_{3m-1}$ is connected to the subpixel **12**A_G and the subpixel **12**B_W, and a (3×m)-th column signal line **26**$_{3m}$ is connected to the subpixel **12**A_B.

Basically, the liquid crystal capacitors LC_3, LC_4 and LC_4', and the retention capacitors C_3, C_4 and C_4', illustrated in FIG. **16**, have the same configurations as those described in the second embodiment with reference to FIG. **7**, and thus the description thereof will be omitted.

Signals in accordance with a color image to be displayed are supplied to the display apparatus **4** from the outside. A video signal VS_R for displaying red color, a video signal VS_G for displaying green color and a video signal VS_B for displaying blue color are generated by a circuit, not illustrated in the figure, on the basis of the signal according to the color image. And the signal output circuit **202** drives a reflective subpixel **12**A_R for displaying red color and a transmissive subpixel **12**B_R for displaying red color using the video signal VS_R for displaying red color. The signal output circuit **202** drives a reflective subpixel $\mathbf{12}A_G$ for displaying green color and a transmissive subpixel $\mathbf{12}B_W$ for displaying white color using a video signal VS_G for displaying green color. And the signal output circuit **202** drives a reflective subpixel $\mathbf{12}A_B$ for displaying blue color using a video signal VS_B for displaying blue color.

FIG. **17** is a schematic plan view for explaining arrangement of various components in the display section of the portion including the (m, n)-th pixel. FIG. **18** is a schematic sectional view of the display section taken on line XVIII-XVIII of FIG. **17**. FIG. **19** is a schematic sectional view of the display section taken on line XIX-XIX of FIG. **17**. FIG. **20** is a schematic sectional view of the display section taken on line XX-XX of FIG. **17**.

As illustrated in FIG. **17**, etc., a larger portion of a pixel **12** is occupied by a reflective subpixel in the display apparatus **4** (reflectiveness is emphasized in design). The display apparatus **4** has a configuration in which reflective display is normally performed by additive mixture of the three primary colors, and transmissive display is performed with higher luminance while ensuring a certain degree of color gamut.

The configuration of a black matrix **52**, illustrated in FIG. **18** to FIG. **20**, is the same as the configuration described in the first embodiment. A color filter is disposed in an area surrounded by the black matrix **52**. And a transparent common electrode **54** covering a whole area including the black matrix **52** and the color filter, and an upper alignment film **55** covering a whole area including the transparent common electrode **54** are disposed. Reference numeral $\mathbf{53}_R$ illustrated in FIG. **18** denotes a red filter, reference numeral $\mathbf{53}_G$ illustrated in FIG. **19** denotes a green filter, and reference numeral $\mathbf{53}_B$ illustrated in FIG. **20** denotes a blue filter. Also, reference numeral $\mathbf{53}_W$ illustrated in FIG. **19** and FIG. **20** denotes a white filter.

Operation of the reflective subpixel is the same as that described in the first embodiment. Operation of the transmissive subpixel is the same as that described in the second embodiment.

The TFT functions as a switching element operating in accordance with a signal from the scanning line **22**. As illustrated in FIG. **18**, the pixel electrode **30**B of the subpixel $\mathbf{12}B_R$ and the pixel electrode **30**A of the subpixel $\mathbf{12}A_R$ are integrally formed. On the basis of a TFT operation in accordance with a scanning signal from the scanning line **22**, a voltage in accordance with a video signal VS_R is applied to these pixel electrodes through the signal line **26** from the signal output circuit **202**.

Also, as illustrated in FIG. **19**, a pixel electrode **30**B" of the subpixel $\mathbf{12}B_W$ and a pixel electrode **30**A" of the subpixel $\mathbf{12}A_G$ are integrally formed. On the basis of a TFT operation in accordance with a scanning signal from the scanning line **22**, a voltage in accordance with a video signal VS_G is applied to these pixel electrodes through the signal line **26** from the signal output circuit **202**.

On the other hand, as illustrated in FIG. **20**, a pixel electrode **30**B" of the subpixel $\mathbf{12}B_W$ is formed independently of the pixel electrode **30**A" of the subpixel $\mathbf{12}A_B$. On the basis of a TFT operation in accordance with a scanning signal from the scanning line **22**, a voltage in accordance with a video signal VS_B is applied to the pixel electrode **30**A" through the signal line **26** from the signal output circuit **202**.

And as illustrated in FIG. **17**, the pixel electrode **30**B" illustrated in FIG. **19** and the pixel electrode **30**B" illustrated in FIG. **20** are integrally formed. Accordingly, as described with reference to FIG. **19**, a voltage in accordance with the video signal VS_G is applied to the pixel electrode **30**B" illustrated in FIG. **20**.

Next, a description will be given of color gamut and luminance of an image displayed on the display apparatus **4**.

For an image based on the reflective subpixels $\mathbf{12}A_R$, $\mathbf{12}A_G$ and $\mathbf{12}A_B$, it is possible to display colors in an area of a triangle having vertices denoted by reference numerals R, G, and B illustrated in FIG. **5**A from additive mixture of colors. On the other hand, for an image based on the transmissive subpixel $\mathbf{12}B_R$ and $\mathbf{12}B_W$, it is possible to display colors in a line segment connecting points denoted by reference numerals W and R in FIG. **5**B from additive mixture of colors. In this regard, in the case of a configuration in which the color filter $\mathbf{53}_W$ illustrated in FIGS. **19** and **20** is replaced by a color filter for displaying cyan, it is possible to display colors in a line segment connecting points denoted by reference numerals C and R illustrated in FIG. **5**B from additive mixture of colors.

Accordingly, it is possible for the display apparatus **4** to display a favorable image by additive mixture of the three primary colors at the time of operating as a reflective type, and to display images having higher luminance while ensuring a certain degree of color gamut at the time of operating as a transmissive type.

Fifth Embodiment

A description will be given of a display apparatus according to a fourth embodiment of the present disclosure. In the fifth embodiment, the configuration of the transmissive subpixels for displaying white color is different from the fourth embodiment.

In a schematic perspective view of a display apparatus according to the fifth embodiment, the subpixels $\mathbf{12}B_W$ illustrated in FIG. **15** ought to be changed for subpixels $\mathbf{12}B_{W1}$ and $\mathbf{12}B_{W2}$, the display section **410** ought to be changed for a display section **510**, and the display apparatus **4** ought to be changed for a display apparatus **5**.

In the display section **510**, a pixel **12** includes a first transmissive subpixel $\mathbf{12}B_{W1}$ and a second transmissive subpixel $\mathbf{12}B_{W2}$ for displaying white color.

A description will be given of details of the subpixels according to the fifth embodiment.

FIG. **21** is a schematic circuit diagram of a display section of a portion including a (m, n)-th pixel according to the fifth embodiment.

A scanning line $\mathbf{22}_n$ of an n-th row is connected to a pixel $\mathbf{12}_{(m,\ n)}$. A signal line $\mathbf{26}_{3m-2}$ of a (3×m−2)-th column is connected to a subpixel $\mathbf{12}A_R$ and a subpixel $\mathbf{12}B_R$. A signal line $\mathbf{26}_{3m-1}$ of a (3×m−1)-th column is connected to a subpixel $\mathbf{12}A_G$ and a subpixel $\mathbf{12}B_{W1}$. A signal line $\mathbf{26}_{3m}$ of a (3×m)-th column is connected to a subpixel $\mathbf{12}A_B$ and a subpixel $\mathbf{12}B_{W2}$.

The liquid crystal capacitors LC_3 and LC_4, and the retention capacitors C_3 and C_4, illustrated in FIG. **21**, have basically the same configurations as those described in the second embodiment with reference to FIG. **7**, and thus the description thereof will be omitted.

Signals in accordance with a color image to be displayed are supplied to the display apparatus **5** from the outside. A video signal VS_R for displaying red color, a video signal VS_G for displaying green color and a video signal VS_B for displaying blue color are generated by a circuit, not illustrated in the figure, on the basis of the signal according to the color image. And the signal output circuit **202** drives the reflective subpixel $\mathbf{12}A_R$ and the transmissive subpixel $\mathbf{12}B_R$ for displaying red color using the video signal VS_R for displaying red color. The signal output circuit **202** drives the reflective subpixel $\mathbf{12}A_G$ for displaying green color and the first transmissive subpixel $\mathbf{12}B_{W1}$ for displaying white color using the video signal VS_G

for displaying green color. And the signal output circuit **202** drives the reflective subpixel **12**A_B for displaying blue color and the second transmissive subpixel **12**B_{W2} for displaying white color using the video signal VS_B for displaying blue color.

FIG. **22** is a schematic plan view for explaining arrangement of various components in the display section of the portion including the (m, n)-th pixel.

FIG. **23** is a schematic sectional view of the display section taken on line XXIII-XXIII of FIG. **22**. In this regard, a schematic sectional view of the display section taken on line XVIII-XVIII of FIG. **22** is the same as that in FIG. **18**. Also, a schematic sectional view of the display section taken on line XIX-XIX of FIG. **22** ought to be obtained by changing reference numeral **12**B_W for reference numeral **12**B_{W1} in FIG. **19**.

Operation of the display apparatus **5** is the same as described in the fourth embodiment except that a transmissive subpixel **12**B_{W2} for white color is driven by the video signal VS_B for displaying blue color.

As illustrated in FIG. **17**, in the display section **410** according to the fourth embodiment, it is necessary that the individual pixel electrodes are different in planar shape. In contrast, in the display section **510** according to the fifth embodiment, it is possible for the individual pixel electrodes to have a same planar shape. Accordingly, the fifth embodiment has an advantage in that the display section **510** is easy to manufacture.

In the above, descriptions have been specifically given of the embodiments of the present disclosure. However, the present disclosure is not limited to the above-described embodiments. Various variations are possible within the spirit and scope of this disclosure.

In this regard, in the present disclosure, it is also possible to employ configurations described as follows.

(1) A display apparatus including

a display section including an array of pixels in a two-dimensional matrix,

wherein each of the pixels of the display section includes a pair of a subpixel displaying a first primary color, and a subpixel displaying a second primary color being different from the first primary color.

(2) The display apparatus according to (1),

wherein the first primary color is red.

(3) The display apparatus according to (1) or (2),

wherein the second primary color is white or cyan.

(4) The display apparatus according to any one of (1) to (3),

wherein the subpixel displaying the first primary color is driven using a video signal for displaying red color, and the subpixel displaying the second primary color is driven using a video signal for displaying green color.

(5) The display apparatus according to any one of (1) to (4),

wherein the display section includes a liquid-crystal display panel.

(6) A display apparatus including

a transflective display section including, in a two-dimensional matrix, an array of pixels including a pair of a transmissive subpixel for displaying red color, a transmissive subpixel for displaying green color and a transmissive subpixel for displaying blue color, and a reflective subpixel for displaying red color and a reflective subpixel for displaying white color or cyan.

(7) The display apparatus according to (6),

wherein the transmissive subpixel for displaying red color and the reflective subpixel for displaying red color are driven using a video signal for displaying red color,

the transmissive subpixel for displaying green color and the reflective subpixel for displaying white color or cyan are driven using a video signal for displaying green color, and

the transmissive subpixel for displaying blue color is driven using a video signal for displaying blue color.

(8) The display apparatus according to (6),

wherein the pixels are provided with a first reflective subpixel and a second reflective subpixel for displaying white color or cyan,

the transmissive subpixel for displaying red color and the reflective subpixel for displaying red color are driven using a video signal for displaying red color,

the transmissive subpixel for displaying green color and the first reflective subpixel for displaying white color or cyan are driven using a video signal for displaying green color, and

the transmissive subpixel for displaying blue color and the second reflective subpixel for displaying white color or cyan are driven using a video signal for displaying blue color.

(9) The display apparatus according to any one of (6) to (8),

wherein the display section includes a transflective liquid-crystal display panel.

(10) A display apparatus including

a transflective display section including, in a two-dimensional matrix, an array of pixels including a pair of a reflective subpixel for displaying red color, a reflective subpixel for displaying green color and a reflective subpixel for displaying blue color, and a transmissive subpixel for displaying red color and a transmissive subpixel for displaying white color or cyan.

(11) The display apparatus according to (10),

wherein the reflective subpixel for displaying red color and the transmissive subpixel for displaying red color are driven using a video signal for displaying red color,

the reflective subpixel for displaying green color and the transmissive subpixel for displaying white color or cyan are driven using a video signal for displaying green color, and

the reflective subpixel for displaying blue color is driven using a video signal for displaying blue color.

(12) The display apparatus according to (10),

wherein the pixels are provided with a first transmissive subpixel and a second transmissive subpixel for displaying white color or cyan,

the reflective subpixel for displaying red color and the transmissive subpixel for displaying red color are driven using a video signal for displaying red color,

the reflective subpixel for displaying green color and the first transmissive subpixel for displaying white color or cyan are driven using a video signal for displaying green color, and

the reflective subpixel for displaying blue color and the second transmissive subpixel for displaying white color or cyan are driven using a video signal for displaying blue color.

(13) The display apparatus according to any one of (10) to (12),

wherein the display section includes a transflective liquid-crystal display panel.

The present disclosure contains subject matter related to that disclosed in Japanese Priority Patent Application JP 2011-100516 filed in the Japan Patent Office on Apr. 28, 2011, the entire contents of which are hereby incorporated by reference.

What is claimed is:

1. A display apparatus comprising:

a transreflective display section including a liquid crystal panel comprising

an array of pixels in a two-dimensional matrix,

a plurality of scan lines,

a plurality of signal data lines,

a scanning circuit for supplying scanning signals and being connected to the plurality of scan lines, and

a signal output circuit for supplying video signals for displaying a red color, a green color, and a blue color and being connected to the plurality of signal lines; wherein,

each of the pixels of the liquid crystal panel includes:

(i) subpixels including (a) a first transmissive subpixel comprising a red filter, (b) a second subpixel comprising a green filter, (c) a third subpixel comprising a blue filter, (d) a first reflective subpixel comprising a red filter, and (e) a fourth subpixel comprising a white filter or a cyan filter, where (1) the second subpixel and the third subpixel are both transmissive subpixels and the fourth subpixel is a reflective subpixel or (2) the second subpixel and the third subpixel are both reflective subpixels and the fourth subpixel is a transmissive subpixel;

(ii) a first transistor that connects a first signal line for supplying a video signal for displaying red color to pixel electrodes of the first transmissive subpixel and the first reflective subpixel in response to an application of a respective scanning signal from a scanning line to a gate electrode of the first transistor;

(iii) a second transistor that connects a second signal line for supplying a video signal for displaying green color to pixel electrodes of the second subpixel and the fourth subpixel in response to the application of the respective scanning signal from the scanning line to a gate electrode of the second transistor; and

(iv) a third transistor that connects a third signal line for supplying a video signal for displaying blue color to a pixel electrode of only the third subpixel in response to the application of respective scanning signal from the scanning line to the gate electrode of the third transistor.

2. The display apparatus of claim **1**, wherein the second subpixel and the third subpixel are both transmissive subpixels and the fourth subpixel is a reflective subpixel.

3. The display apparatus of claim **1**, wherein the second subpixel and the third subpixel are both reflective subpixels and the fourth subpixel is a transmissive subpixel.

4. The display apparatus of claim **1**, wherein an area of the first transmissive subpixel is different than an area of the fourth subpixel.

5. The display apparatus of claim **4**, wherein the area of the first transmissive subpixel is smaller than the area of the fourth subpixel.

6. The display apparatus of claim **1**, wherein an area of the first reflective subpixel is different than an area of the fourth subpixel.

7. The display apparatus of claim **6**, wherein the area of the first reflective subpixel is smaller than the area of the fourth subpixel.

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